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Canopy Penetration In Almond Orchards

Part 2: FSCBG Simulation of Drop Deposition and Downwind Drift

FHTET 96-03
February 1996

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FHTET 96-03
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February 1996

CANOPY PENETRATION IN ALMOND ORCHARDS

PART 2:

FSCBG SIMULATION OF DROP DEPOSITION AND DOWNWIND DRIFT

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Executive Summary

This paper presents the results of an aerial spray drop deposition study in an almond orchard. The field trials were conducted by the USDA Forest Service and cooperators at Hennigan Orchard, Chico, CA, during February and March 1994. The objective of the study was to evaluate the deposition of the insecticide ***Bacillus thuringiensis*** (Bt), under different foliage conditions of an almond orchard, applied with different application rates and techniques, and to compare observed deposition with that predicted by the USDA Forest Service Cramer-Barry Grim (FSCBG) aerial spray model. For each stage of foliage (blossom expansion and petal fall), a formulation of Bt was applied aerially in three phases. Each phase represented a different set of replicated applications. The spray was sampled with Kromekote cards attached to beverage cans and placed in the orchard and upper canopy. FSCBG model simulation results compared to observed field data are presented for each phase of the field study and for each stage of foliage development. FSCBG reasonably predicts canopy effects with good correlation of average predicted deposition to the field test data throughout the canopy and into downwind drift, demonstrated for the ultra low volume application.

Executive Summary

This paper presents the results of an aerial spray drift [illegible] study [illegible] (Dursban) [illegible]. The field trials were conducted by the USDA Forest Service and [illegible] Ukiah, CA [illegible] during [illegible]. The objective of the study was to [illegible] the deposition of the [illegible] thuringiensis (Bt), under different canopy conditions [illegible] aircraft [illegible] application [illegible] and [illegible] by the USDA Forest Service [illegible]. The [illegible] stage of foliage [illegible] expansion and [illegible], a [illegible] applied [illegible] phases. Each phase represents a different [illegible] of [illegible] applications. The spray was [illegible] with [illegible] to [illegible] in the [illegible] and [illegible]. FSCBG model [illegible] observed field data are presented for each phase of the field study and for [illegible] foliage development. FSCBG [illegible] predicted canopy [illegible] average predicted deposition to the field [illegible] drift [illegible] for [illegible] applications.

Table of Contents

1. Introduction

Field trials conducted at Hennigan Almond Orchard, Chico, CA, in February and March of 1994 provide a comprehensive set of spray deposit data through a broadleaf canopy. Accurate modeling of canopy effects is an important factor in the evaluation of field trials involving aerial application over forests, orchards, and other tree canopies. The 1994 Hennigan trials were conducted in identical fashion at two stages of flower and foliage: popcorn (bloom expansion) and blossom petal fall (at petal fall time, new leaves have begun to emerge from the bud). Beverage can samplers were used to collect spray deposits within the canopy. Samplers were placed at two heights, near the ground and at mid-canopy level, at forty locations during each phase of testing. Each can sampler yielded deposit data from its top and sides. These data have been evaluated in Part 1 of this study (MacNichol, 1996) to assess deposition effectiveness throughout the orchard canopy during each phase of testing and for each stage of flower and foliage.

The purpose of this report is to simulate drop and volume deposition within a broadleaf canopy using data from the tops of the can samplers. Downwind drift is also evaluated using data from cards placed at ground level outside the canopy for certain portions of the field trials. The Forest Service Cramer-Barry-Grim (FSCBG) aerial spray model (Teske et al., 1993b) is used to model the orchard canopy and predict the levels of deposition expected at the two stages of flower and foliage, and to predict downwind drift. Predicted levels of deposition are then compared to the top-of-can deposit data throughout the canopy and to the ground card data.

The USDA Forest Service in cooperation with the U.S. Army has developed the FSCBG aerial spray model and its near-wake Agricultural Dispersal (AGDISP) model (Bilanin et al., 1989). FSCBG predicts the transport and behavior of sprays released from aircraft, influenced by the aircraft wake and local atmospheric conditions, through downwind drift and deposition to total accountancy and environmental fate. The AGDISP near-wake representation solves a Lagrangian system of equations for the position and position variance of material released from each nozzle on the spray aircraft. The FSCBG far-wake representation begins with the results of AGDISP at the top of a canopy or near the ground, and solves a Gaussian diffusion equation to recover canopy and ground deposition.

Technical aspects of the FSCBG model are discussed by Teske et al. (1993b). Previous comparisons with data are numerous and include a series of validation studies accomplished since 1993 (MacNichol and Teske, 1993a, 1993b, 1994a, 1994b, 1995). Studies which have used FSCBG canopy modeling capabilities for coniferous canopies include: MacNichol and Teske (1994b), Douglas-fir; Rafferty et al. (1982), Southern pine; and Teske et al. (1991), Douglas-fir. Several other studies have evaluated oak canopies: Anderson et al. (1992), eastern oak; Rafferty and Grim (1992), Gambel oak; and Teske, Barry and Rafferty (1994), Gambel oak. Broadleaf canopies have been previously modeled with FSCBG (Teske et al., 1993a), but this report presents the first known detailed evaluation of a broadleaf canopy at different stages of tree growth.

2. Field Trials Summary

2.1 Scope of the Field Trials

In early 1994 a series of spray trials was conducted at Hennigan Almond Orchard (Zalom et al., 1994). These trials were a cooperative effort among grower Bob Hennigan, the University of California Extension, Entotech, Inc. and the USDA Forest Service. The trials took place from January to March, and were designed to represent two stages of tree foliage, popcorn (bloom expansion) and blossom petal fall. Since the objective of this study was to evaluate the effectiveness of the biopesticide *Bacillus thuringiensis* (Bt) in controlling peach twig borer, the spray material used was a NOVO insecticide that uses Bt as its active ingredient.

There were four phases of this aerial application study: Phase A, a conventional chemical treatment applied in January during tree dormancy; and Phases B, C and D, different tank mixes of Bt applied once on February 22 when the foliage was in its popcorn stage and repeated on March 8 when the foliage was in its blossom petal fall stage. The scope of the field trials is summarized in Table 1. Each phase of testing represented a type of application. Phase A, representing conventional high volume treatment applied with a helicopter, provided a baseline for comparison of Bt treatments to the standard treatment methods; data from this phase are not used in this report. Phases B and C represented low-volume and high volume Bt treatments, respectively, applied with a helicopter and CP nozzles; Phase D represented ultra low volume (ULV) Bt treatments applied with a fixed-wing airplane and Micronair rotary atomizers.

The orchard was divided into 20 plots, as shown in Figure 1. The aircraft flew over four plots during each treatment phase. In each plot, can samplers were placed at ten locations in the canopy (all at mid-canopy height) and ten locations below the canopy, 0.46 meters above the ground. Thus, there are data from forty mid-canopy samplers, and forty samplers below the canopy, for each phase of the trials. Although there is no way to ascertain relative penetration at different heights within the canopy, penetration to mid-canopy and penetration through the canopy to ground-level can be evaluated. Note that, with the exception of plots #19 and 20, no plots in a given phase were contiguous and they were randomly assigned for treatment.

To evaluate downwind drift during the trials, Kromekote sampler cards were placed at ground level south of plots 6 (Phase B), 10 (Phase C) and 18 (Phase D) on March 8, when the foliage was in the blossom petal fall stage. The cards started at the south edge of the plots (as shown in Figure 1) and continued across the road into the next orchard for 200 feet: 20 samplers were placed 10 feet apart.

The Hennigan trials are described in a study plan (Zalom et al., 1994).

2.2 Spray Site

Orchard characteristics at the time of the field trials are given in Table 2. For the purposes of the FSCBG simulation, the entire orchard must be assumed to be uniformly

distributed during each stage of foliage. The tree envelope used in the FSCBG canopy model is based on a typical broadleaf tree of the dimensions given in Table 2, and is shown in that table as well.

Figure 2 shows the location of the can samplers for the field trials. As previously mentioned, the orchard was divided into 20 plots of various sizes, with each phase being conducted over four plots. The twelve plots which comprised Phases B through D ranged in size from 8.1 to 16.3 acres. In the center of each plot five adjacent sample trees were selected. Two beverage can samplers were placed at mid-canopy height (4.6 meters), one on the east side of the tree and one on the west side. The samplers were attached to the tops of PVC pipes placed 1.2 meters inside the tree dripline. Two more can samplers were placed 0.46 meters above the ground, directly underneath the canopy samplers and well within the tree dripline.

The beverage can samplers used in the field trials consisted of Kromekote cards wrapped on the sides of empty aluminum soft drink cans, with squares of Kromekote attached to the tops of the cans as well. The can samplers had 40 square centimeters of card surface on top, and the sides of the cans were completely wrapped.

Ground cards used to assess downwind drift were also Kromekote cards.

2.2 Meteorological Measurements

Two EMCOT weather stations were positioned as shown in Figure 1 to recover meteorological data during the trials. Tower 1 was located outside the spray area, about 61 meters (200 feet) northwest of the northern edge of plot 5, and tower 2 was located in the orchard, in the center of plot 19 (private communication with J.W. Barry, USDA Forest Service). Meteorological data collected included temperature, wind direction and wind speed at 0.5 meters and 7.0 meters, and relative humidity at 0.5 meters. Net radiation was also measured. Azimuthal standard deviation and elevation angle deviation were recovered from one-second wind direction data. EMCOT weather stations are described in detail in Ekblad, Widnall and Thompson (1990).

Table 3 summarizes the meteorological conditions during each phase of the trials. Data given in this table represent an average of each meteorological variable of interest over the entire time of spraying for each phase. It should be noted that the spray times range in duration from 30 minutes to 70 minutes, and all were conducted in the late morning to mid-afternoon (between 11:15 AM and 3:00 PM). Since Station 1 was outside the canopy and Station 2 was inside, the effect of the canopy on wind speed can clearly be seen at both heights for which there were measurements made. Although wind direction measurements over the time periods indicated showed very large fluctuations, average values at each station do not vary much with height.

2.3 Aircraft and Spray Systems

Table 4 summarizes the aircraft and spray systems used in each phase of the Hennigan trials. The fixed-wing airplane flown was an Ag Cat, with a spray system

consisting of six Micronair rotary atomizers placed along the microfoil boom of the airplane. The helicopter flown was a Bell Jet Ranger 206 helicopter whose spray system consisted of CP plastic nozzles, 20 for Phase B and 60 for Phase C. Flight speeds of each aircraft were 13.4 m/sec for the helicopter and 49.2 m/sec for the fixed-wing aircraft. Release height above the mean canopy top was 1.5 meters. Application rates during the trials varied from ULV (0.5 gal/acre for Phase D) to high volume (15 gal/acre for Phase C).

As previously mentioned, the material sprayed was NOVO Biobit XL, with blue, grape and black dyes mixed in for Phases B, C and D, respectively.

The spraying aircraft flew multiple passes over plots that contained sample trees in their centers. The aircraft flew in 12.5 meter swaths, north-to-south or south-to-north, over all of the plots in a given phase (e.g., plots 9, 10, 11, and 12 for Phase C). Since the Hennigan trees were spaced 8.1 meters center-to-center, the aircraft did not necessarily fly directly over the sample trees in every plot.

2.4 Data Reduction Procedure

The beverage can samplers were positioned the morning of the scheduled spray day and retrieved the same day, after spraying. The tops and sides of the samplers were then assessed for number and size of drop stains and spray volume. Sides and tops of cans were both assessed visually by counting and measuring drop stain diameters. Data were then processed through the Automatic Spot Counting and Sizing System ASCAS data program (Teske, 1992). Side-of-can data reduction was discussed in Part 1 of this report (MacNichol, 1996).

Downwind drift cards were positioned and collected at the same time as the beverage can samplers and were assessed using ASCAS.

Drop size and density data, drop deposition data (in drops per square centimeter) and volume deposition data (in ounces/acre) were generated for each top-of-can sampler and for the downwind drift cards.

2.5 Field Test Deposition Data

FSCBG modeling assumes that the orchard canopy is uniformly distributed on each day of testing. The plots which comprised each phase of application were scattered around the orchard, and the exact position of the spray aircraft over a given set of sample trees was not recorded, although the aircraft flew evenly spaced swaths. The meteorological data available for each phase of application were average values that were not necessarily recorded near a specific set of sample trees. Since a uniform canopy is assumed, and since trials were conducted over similar periods of time during the day, meteorological conditions inside the canopy must be assumed to be uniform from sampler location to sampler location at each elevation. Indeed, it was shown in Part 1 of this report (MacNichol, 1996) that, for each phase of application, the samplers around each tree

experience similar canopy effects at each elevation regardless of the plot they were found in, and regardless of their position with respect to the tree centerline.

Thus, data from the four plots in each phase of spraying are shown as repetitions of one set of data, with two sets of data for each tree (one at mid-canopy and one near the ground). Figure 3 shows the positions assigned to each of the five sample trees. North-south tree position is shown on the x-axis and deposition is shown on the y-axis. Sample tree #3 is arbitrarily assigned a location of 0 meters; each tree is separated by 8.1 meters. Thus, the data from tree #1, mid-canopy, from all four plots in this phase, is assigned to one sample location: -16.2 meters. The figure shows the scatter in the data at each tree position, principally from the fact that the flight lines are spaced differently from the sample trees from plot to plot.

Data from the can samplers placed above ground level (at 0.46 meters) will henceforth be referred to as "ground" data.

The field test data for each phase of application on each day of testing are shown in Figures 4 through 9. Each of these figures shows deposition in drops per square centimeter followed by volume deposition in ounces per acre. Average deposition values at mid-canopy and ground level are shown as dotted lines. Table 5 shows the average field test deposition, by phase, for the following positions in the canopy: mid-canopy east samplers, mid-canopy west samplers, all mid-canopy samplers; ground east samplers, ground west samplers, all ground samplers; and all samplers, mid-canopy and ground. As previously mentioned, all field test canopy data shown in this report are from the tops of the beverage can samplers.

The scatter in the field test data for a given tree location within the sample plots is readily apparent. Close examination of the field test data did not indicate any pattern to the scatter (in other words, the very large and very small values of deposition do not all occur at particular locations within a plot, nor do they occur only in certain plots in a phase). It is known that the spray aircraft flew down either the centerline of sample trees in each plot or between tree rows (J. W. Barry, private communication, 1995), but its exact location was not measured. Also, as can be seen in Figure 1, the sample plots in a given phase were scattered all over the orchard, and the canopy may not have been completely uniform (consistent with another almond orchard study, Roltsch et al., 1995). Meteorological conditions at each plot also could have varied, particularly wind speed and direction.

In some of the trials, there are several instances where drop and volume deposition recorded at sampler locations surrounding a specific tree were higher on the ground than in the canopy. This is especially noticeable in the data from February 22, Phase B (Figure 4), March 8, Phase B (Figure 7) and March 8, Phase D (Figure 9). Although it is not readily apparent from the figures shown here, in each of these trials the ground deposition is much higher than the mid-canopy deposition at specific places within sample plots, consistent with the fact that the canopy had gaps, and was not as continuous as assumed. Thus, the canopy was not capturing all of the spray (spray may have been coming in at more of an angle than is indicated by the meteorological and spray system data provided).

Another possible cause of large ground deposition may have been splatter of the largest drops passing through the canopy. If the largest drops entering the canopy

splattered as they hit elements of foliage, the resulting smaller droplets would have continued to pass through the canopy, and many would have eventually reached the ground. For the Phase B trials, the combination of larger particle size (due to a nozzle spray system) and the helicopter downwash (which tends to drive spray more forcefully through the canopy) may well have resulted in significant splatter and more penetration of the spray to the ground level samplers.

The average field test deposition values in Table 5 show little variation in the average drops deposited east and west of the tree centerline (again consistent with Roltsch et al., 1995). Average volume deposition values on either side of the tree centerline are within 15 percent of each other, with the exception of February 22, Phase C ground deposition (east and west differ by over 20%) and March 8, Phase D canopy deposition (east and west differ by over 40%). For the rest of this report, the average field test deposition at each elevation will be used when making comparisons with FSCBG model predictions.

In addition to drop and volume deposition data, droplet size data are also available. Volume Median Diameter (VMD) and Number Median Diameter (NMD) are given for each top-of-can sampler position. As was true for the drop and volume deposition data, VMD and NMD show a great deal of scatter for a given tree location within the sample plots. There appears to be no pattern to the scatter with respect to tree location in the plots, or to sampler location east or west of the sample line of trees. As expected, the VMD of droplets observed during Phases B and C was much higher than during Phase D (Phase D was sprayed with the Micronair rotary atomizers, which produce a very fine spray).

Table 6 shows the droplet size data observed during the trials, averaged for each phase of testing and each stage of foliage. When averaged over an entire phase, the VMD of droplets observed in the canopy is higher for each phase of testing, and on each day of testing, than the VMD of droplets at ground level. This is to be expected, since the canopy is capturing more of the larger droplets. The average VMD of droplets observed during treatment of foliage in the popcorn stage (February 22) was higher than the average VMD observed during the petal fall stage (March 8). The average NMD of droplets observed during both phases of treatment is similar, and there was not much difference between the average NMD observed in the canopy and on the ground.

The droplet size data are compared to FSCBG model predictions in Section 3.

Table 1: Scope of the 1994 Hennigan Trials

Plot	Acres	Phase	Aircraft/Nozzle Type	Nozzles	Tank Mix[1]	Applic. Rate
1	10.9	A	Bell 206 / CP	64	Supracide	20.0 gal/acre[2]
2	8.1	A	Bell 206 / CP	64	Supracide	20.0 gal/acre
3	8.1	A	Bell 206 / CP	64	Supracide	20.0 gal/acre
4	108.0	A	Bell 206 / CP	64	Supracide	20.0 gal/acre
5	16.3	B	Bell 206 / CP	20	Bt (14.6 BIU)[3]	5.0 gal/acre
6	10.9	B	Bell 206 / CP	20	Bt (14.6 BIU)	5.0 gal/acre
7	8.1	B	Bell 206 / CP	20	Bt (14.6 BIU)	5.0 gal/acre
8	8.1	B	Bell 206 / CP	20	Bt (14.6 BIU)	5.0 gal/acre
9	16.3	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
10	10.9	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
11	8.1	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
12	8.1	C	Bell 206 / CP	60	Bt (14.6 BIU)	15.0 gal/acre
13	8.1	UNTREATED Control				
14	10.9	UNTREATED Control				
15	8.1	UNTREATED Control				
16	8.1	UNTREATED Control				
17	16.3	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre
18	10.9	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre
19	8.1	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre
20	8.1	D	Ag Cat / Micronair	6	Bt (24 BIU)	0.5 gal/acre

1. The tank mix for Phases B, C, and D consisted of undiluted Bt with Blue #5601, Grape #5758, and Rhodamine WT liquid dyes, respectively, and water (Phase D was undiluted).

2. Phase A was a conventional chemical treatment applied in January, 1994 during tree dormancy. The tank mix for this treatment consisted of 6 lbs. Supracide, 2 gal. oil, 7% zinc, water and Rhodamine liquid dye. Data from Phase A are not considered in this report.

3. Bt was NOVO Biobit XL.

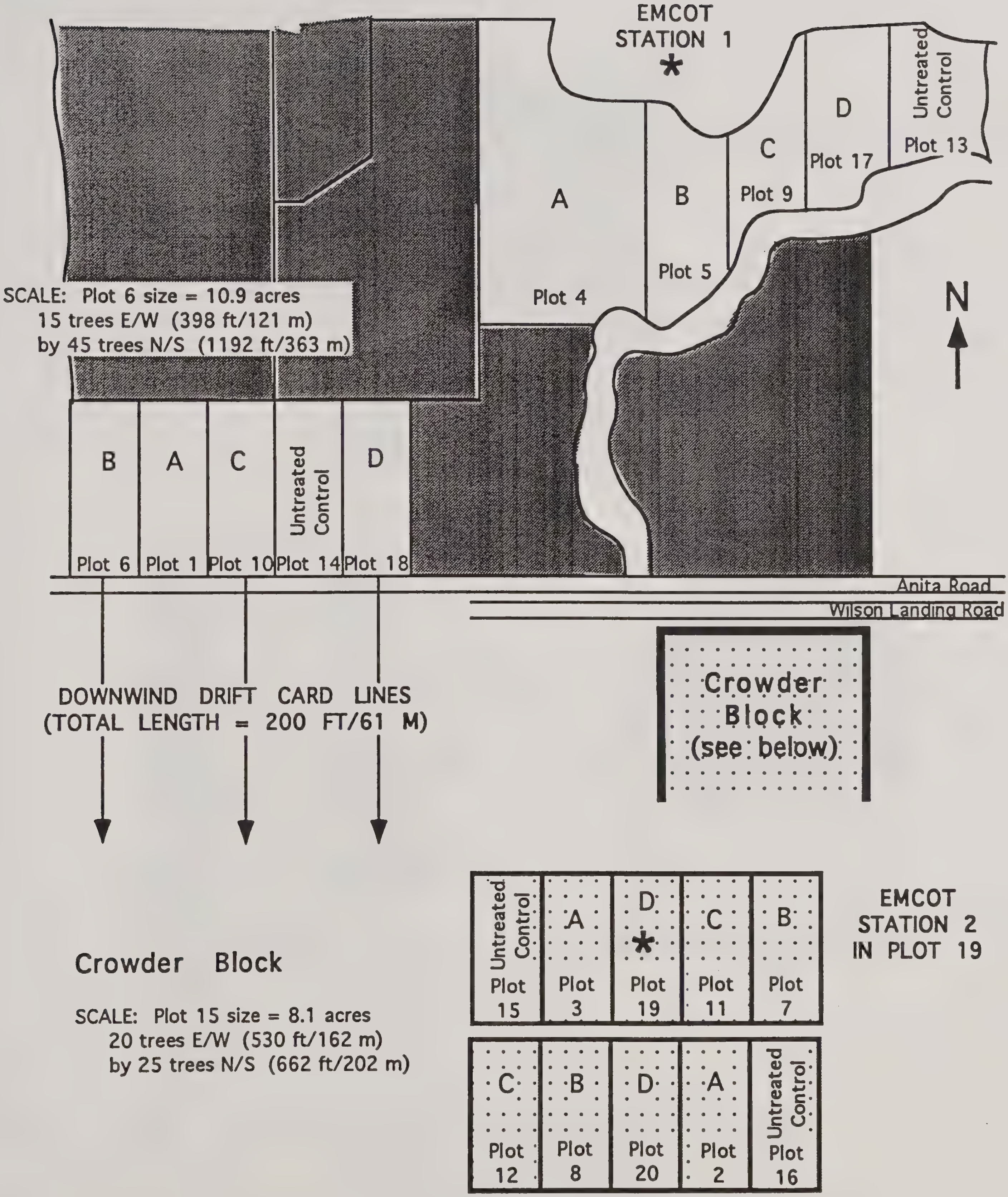


Figure 1: Schematic of Hennigan Almond Orchard (Chico, CA) showing plot layout for the 1994 trials and EMCOT meteorological stations. Shaded areas of the orchard were not used during the trials.

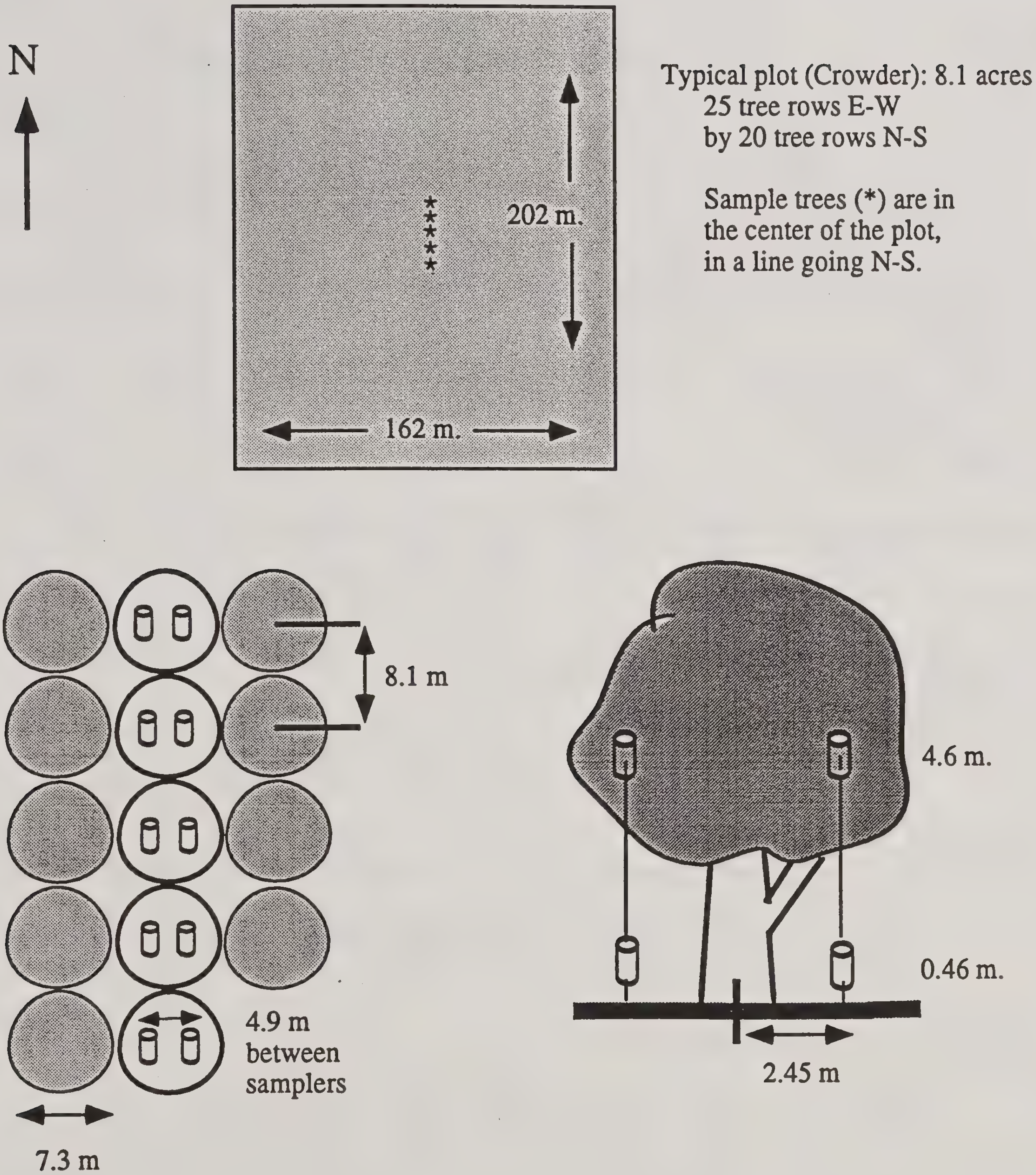
Table 2: Hennigan Almond Orchard Characteristics

Mean Canopy Height (m)	7.6
Tree Separation, center-to-center (m)	8.1
Stand Density	62 stems/acre
Tree Stage	Popcorn (Feb)[1] Blossom Petal Fall (Mar)[1]
Crown Diameter (m)	7.3

TREE ENVELOPE

Height (m)	Diameter (m)
1.04	0.30
2.09	2.60
3.13	5.35
6.26	7.30
7.62	0.

1. These are bloom stages; popcorn refers to bloom expansion.



Hennigan Almond Orchard, 1994:

- trees are 8.1 m. center-to center
- mean canopy height = 7.6 m.
- 5 sample trees in the center of each plot
- 4 can samplers placed in each tree, two at 0.46 m and two at mid-canopy
- samplers are 2.45 m from tree centerline

Figure 2: Placement of sample trees and beverage can samplers in Hennigan Almond Orchard for the 1994 trials.

Table 3: Average Meteorology During the Hennigan Trials

Date/Phase	Temperature (deg. C)		Wind Speed (m/s)		Wind Dir. (deg[1])		RH (%)	Spray Time
Height (m)	7	0.5	7	0.5	7	0.5	0.5	---
February 22: ALL								
Station 1[2]	13.6	13.7	4.07	3.59	305	307	43	1300 to 1410
Station 2	13.8	13.8	2.39	1.73	316	315	42	
March 8: B								
Station 1	19.2	18.9	1.61	1.62	255	316	62	1115 to 1152
Station 2	19.9	19.3	1.11	0.74	284	282	56	
March 8: C								
Station 1	20.7	20.0	1.43	1.50	287	296	56	1215 to 1250
Station 2	21.1	20.4	1.21	0.87	228	227	52	
March 8: D								
Station 1	23.3	22.4	1.30	1.34	303	305	43	1430 to 1500
Station 2	23.9	22.9	0.99	0.60	250	245	40	

1. Wind direction was measured in degrees from magnetic North.

2. Station 1 was outside the orchard. Station 2 was inside the orchard, as shown in Figure 1.

Table 4: Aircraft and Spray Systems for Each Phase of the Trials

Phase	Plots	Aircraft	Speed (m/sec)	Release Height[1] (m)	Nozzle or Atomizer Type/ Application Rate[2]
Hennigan 94					
B	5 - 8	Bell 206	13.4	1.52	CP Nozzles ...... 5.0 gal/acre
C	9 - 12	Bell 206	13.4	1.52	CP Nozzles ...... 15.0 gal/acre
D	17 - 20	Ag Cat	49.2	1.52	Micronair Atomizers ...... 0.5 gal/acre

1. Release height above canopy. Mean canopy height for all trials = 7.6 meters.
2. The formulations sprayed are described in Table 1.

For the purposes of plotting field deposition,
the line of sample trees is presented along
the x-axis, with arbitrarily assigned positions :

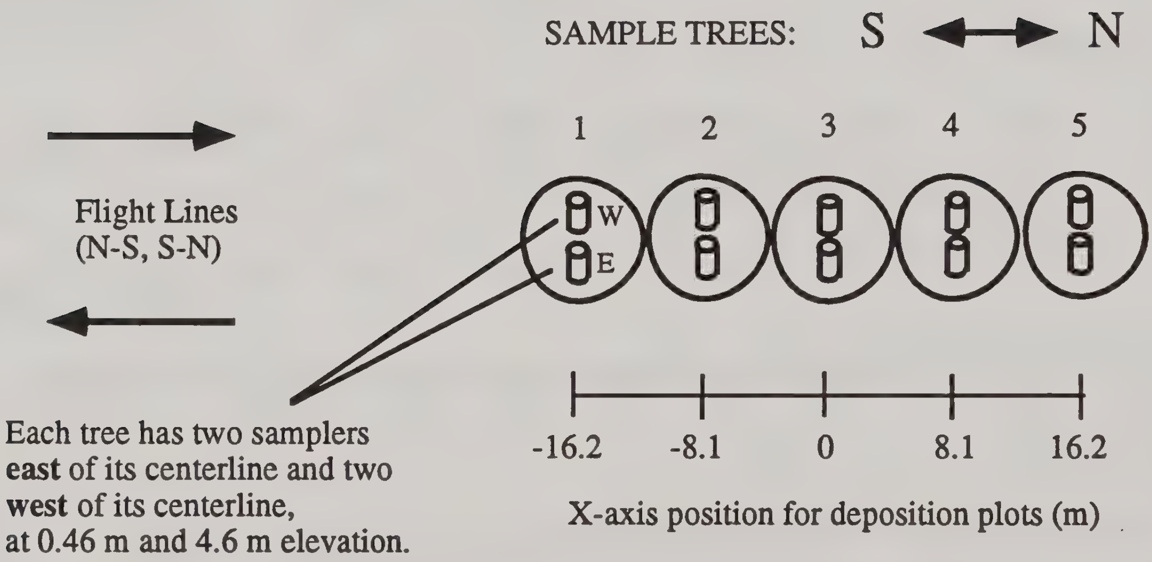
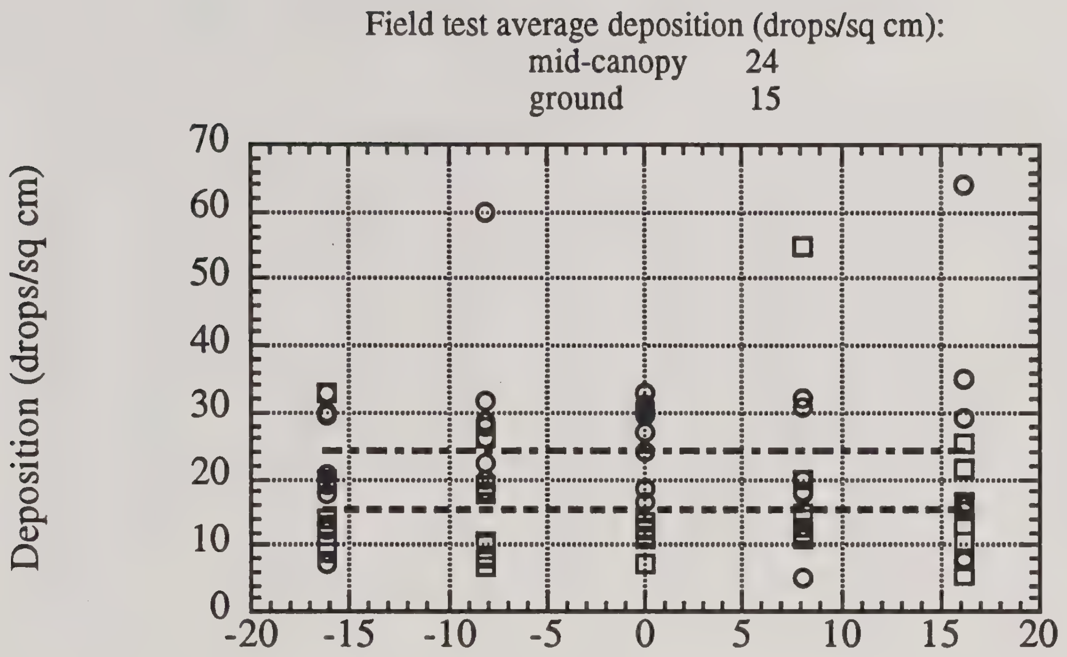


Figure 3: Tree positions for presentation of field test data.



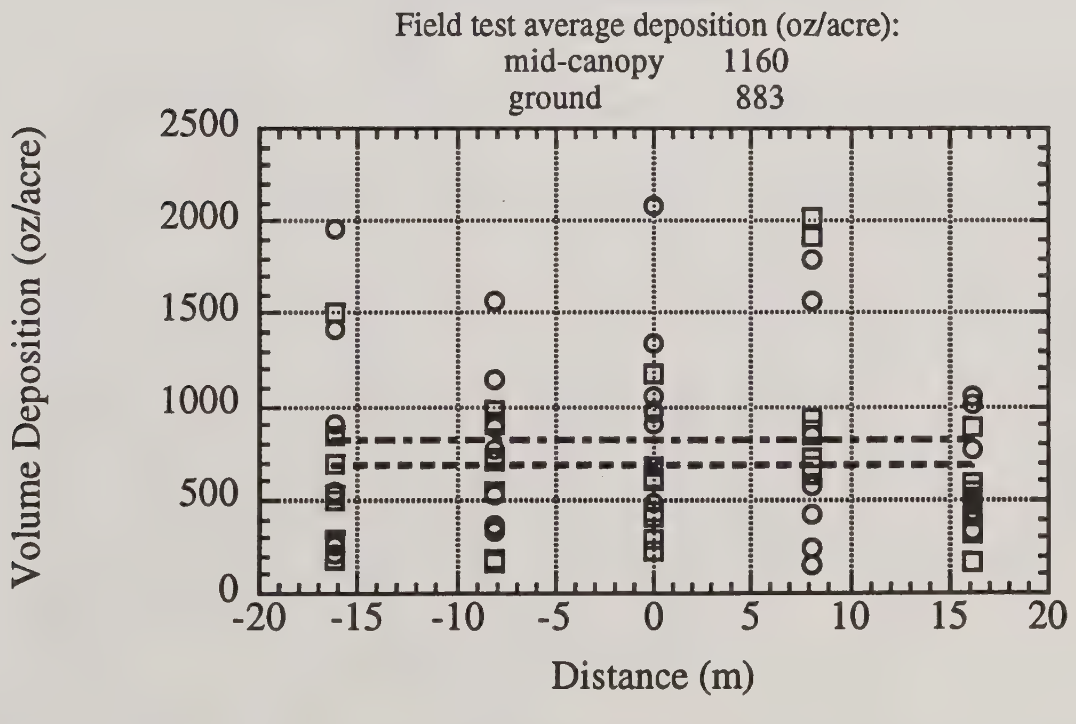
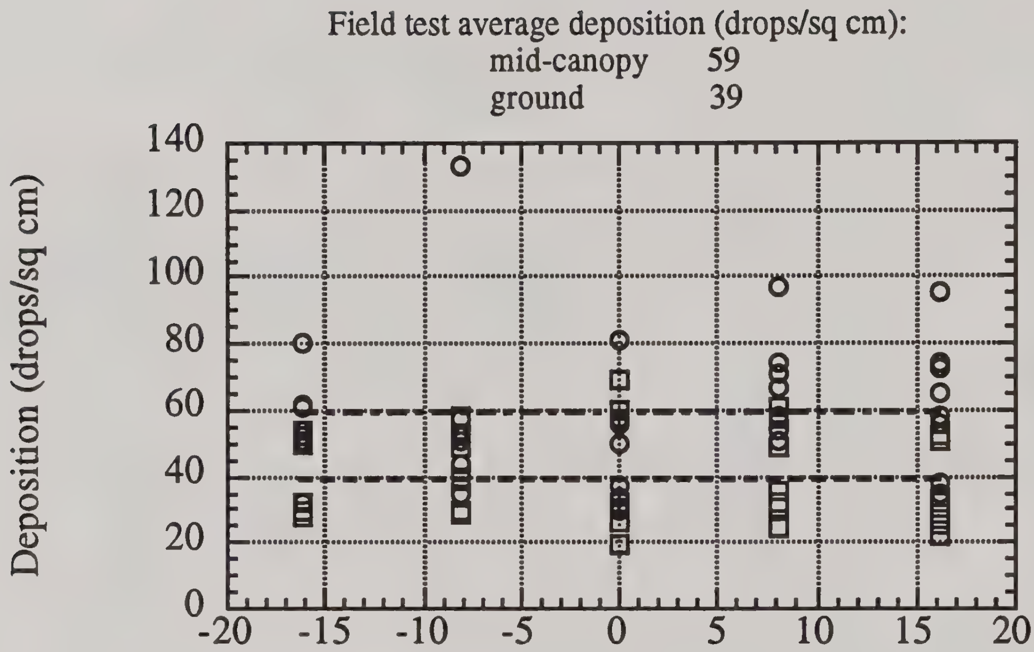


Figure 4: February 22, Phase B field test deposition in drops per square cm and ounces per acre for beverage can collectors at mid-canopy (circles) and ground (squares). Average values for mid-canopy and ground are shown by dashed lines and specified above each plot.



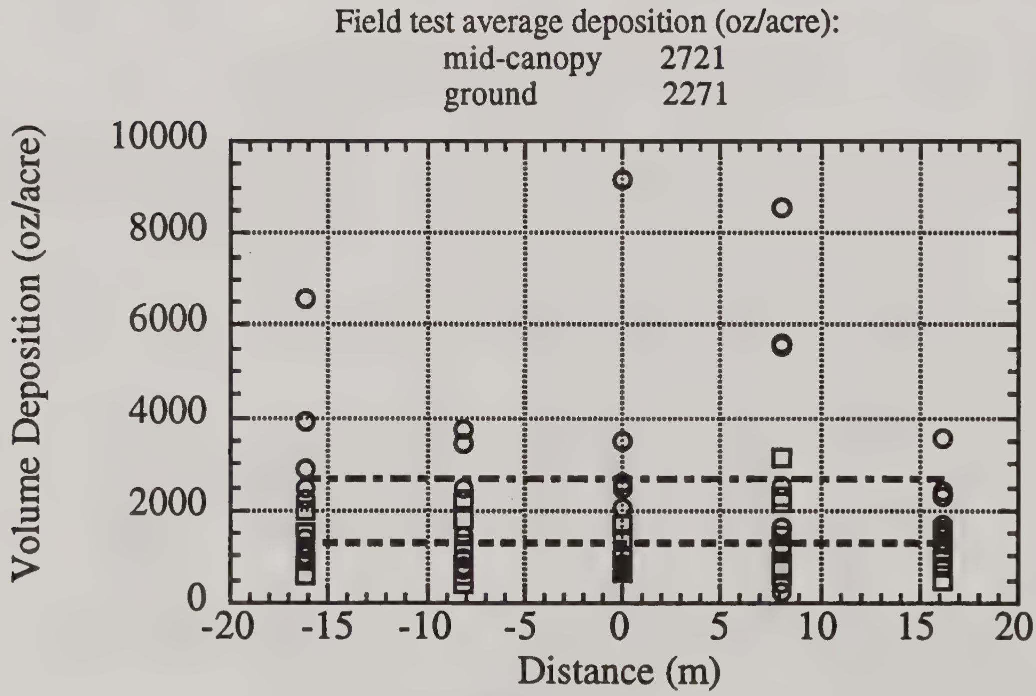
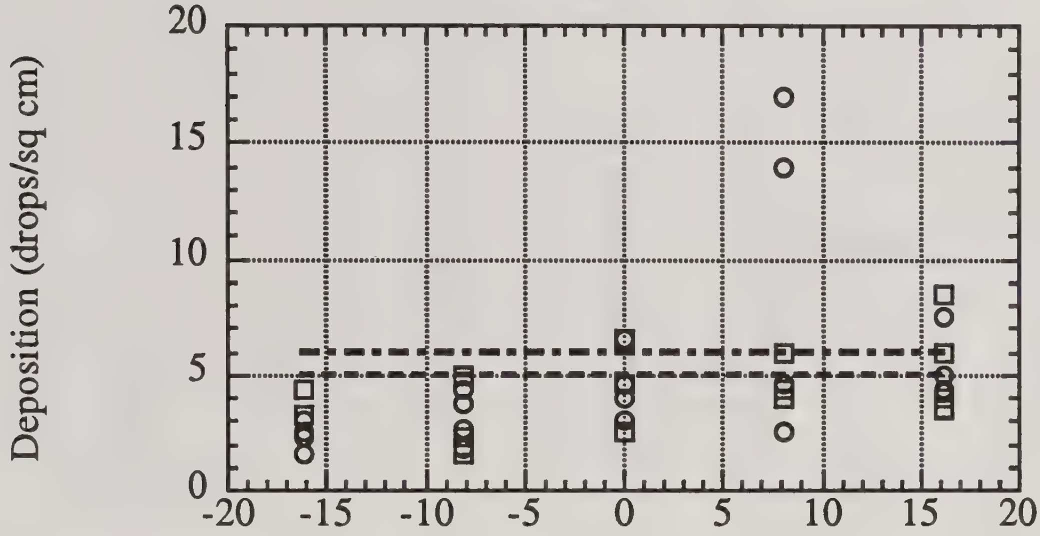


Figure 5: February 22, Phase C field test deposition in drops per square cm and ounces per acre for beverage can collectors at mid-canopy (circles) and ground (squares). Average values for mid-canopy and ground are shown by dashed lines and specified above each plot.

Field test average deposition (drops/sq cm):
mid-canopy 6
ground 5



Field test average deposition (oz/acre):
mid-canopy 19.2
ground 14.4

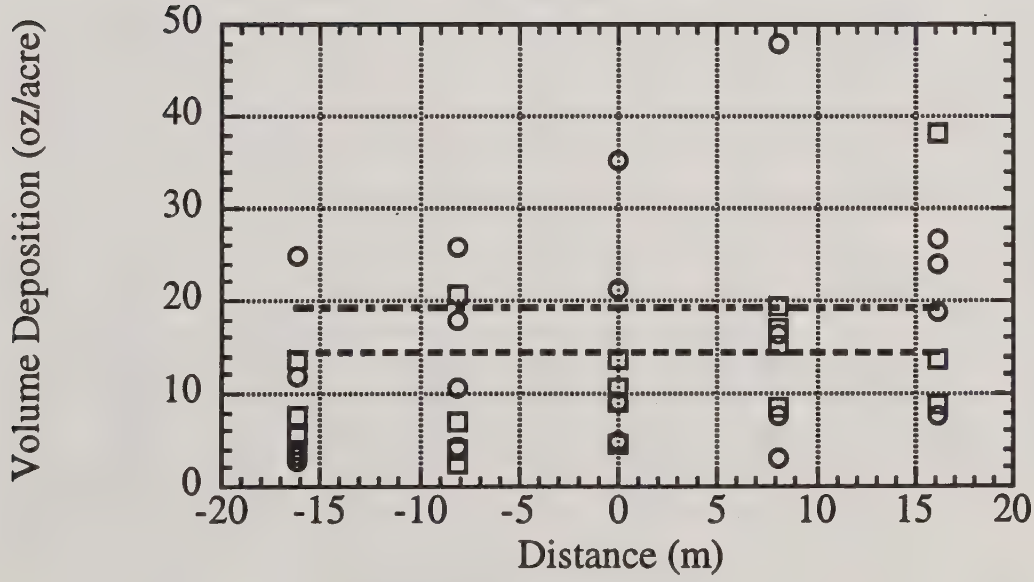
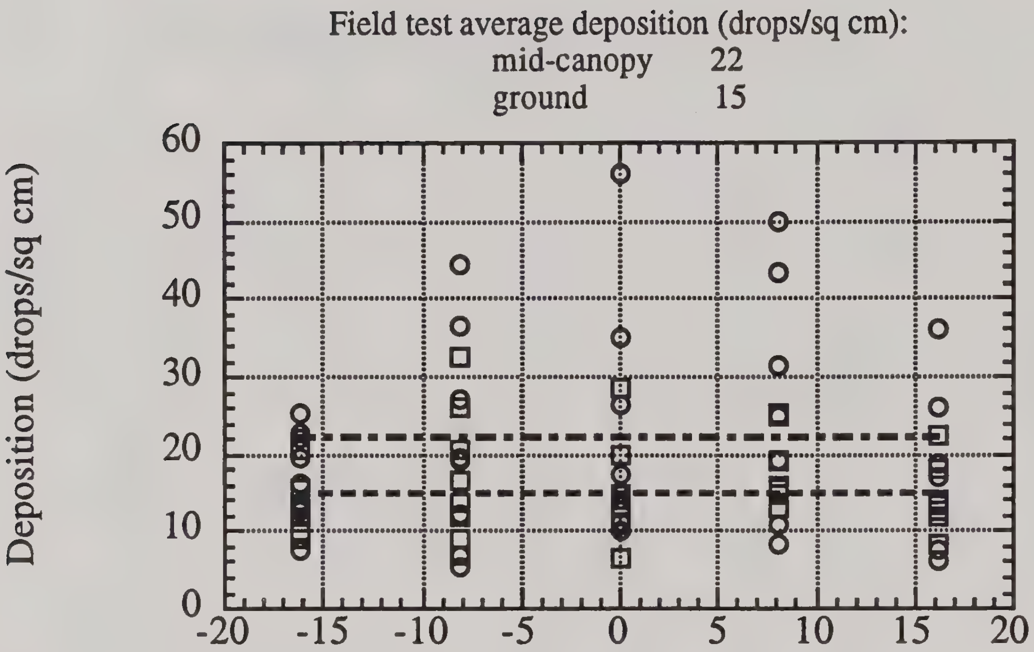


Figure 6: February 22, Phase D field test deposition in drops per square cm and ounces per acre for beverage can collectors at mid-canopy (circles) and ground (squares). Average values for mid-canopy and ground are shown by dashed lines and specified above each plot.



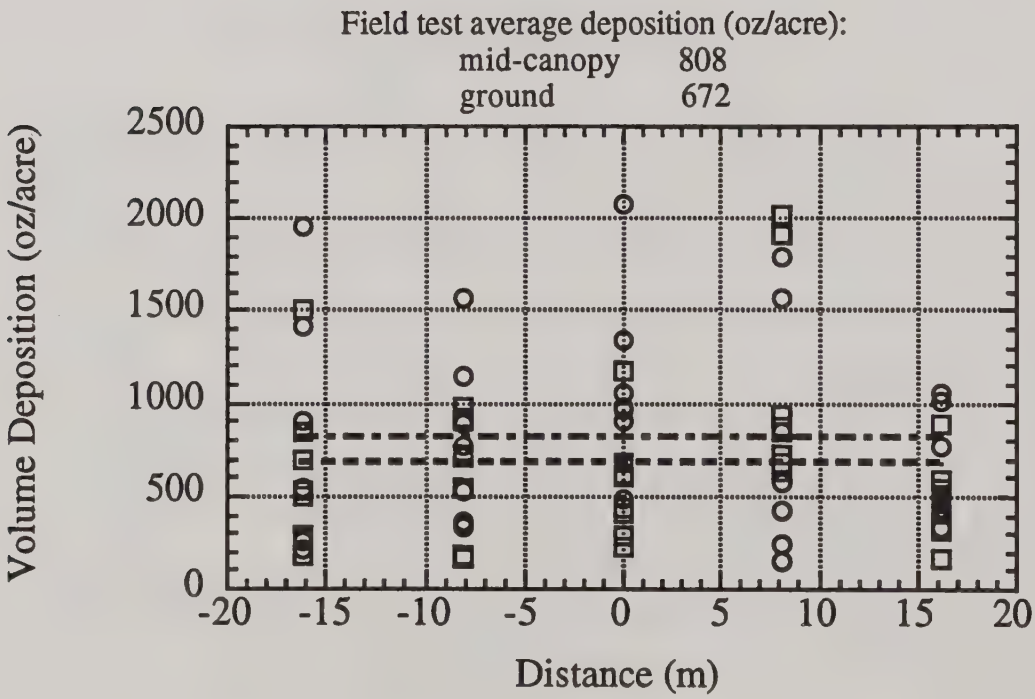
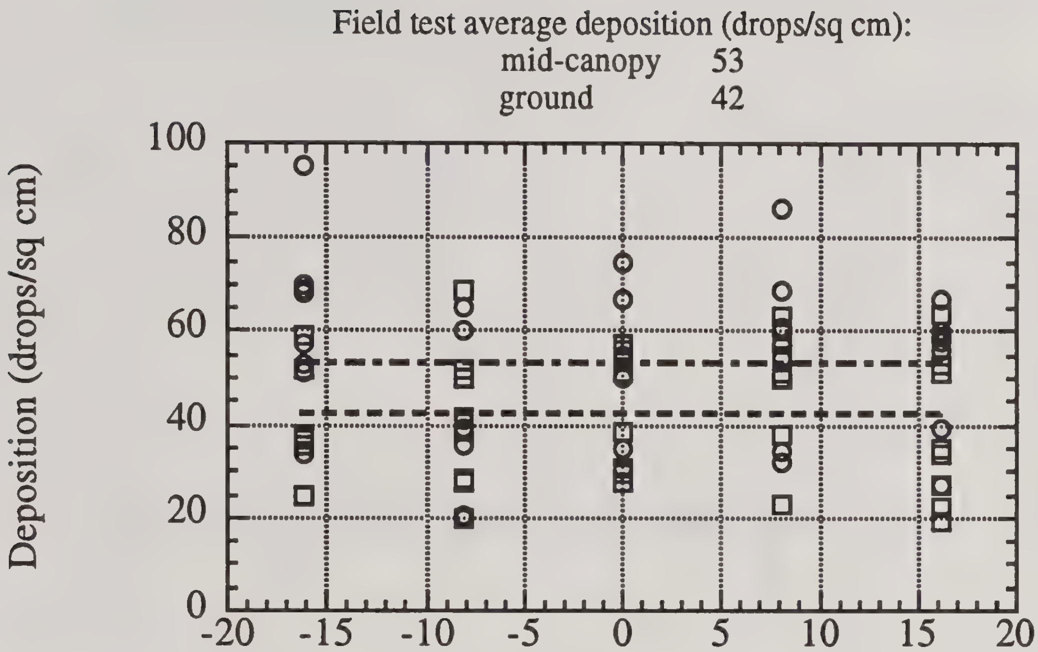


Figure 7: March 8, Phase B field test deposition in drops per square cm and ounces per acre for beverage can collectors at mid-canopy (circles) and ground (squares). Average values for mid-canopy and ground are shown by dashed lines and specified above each plot.



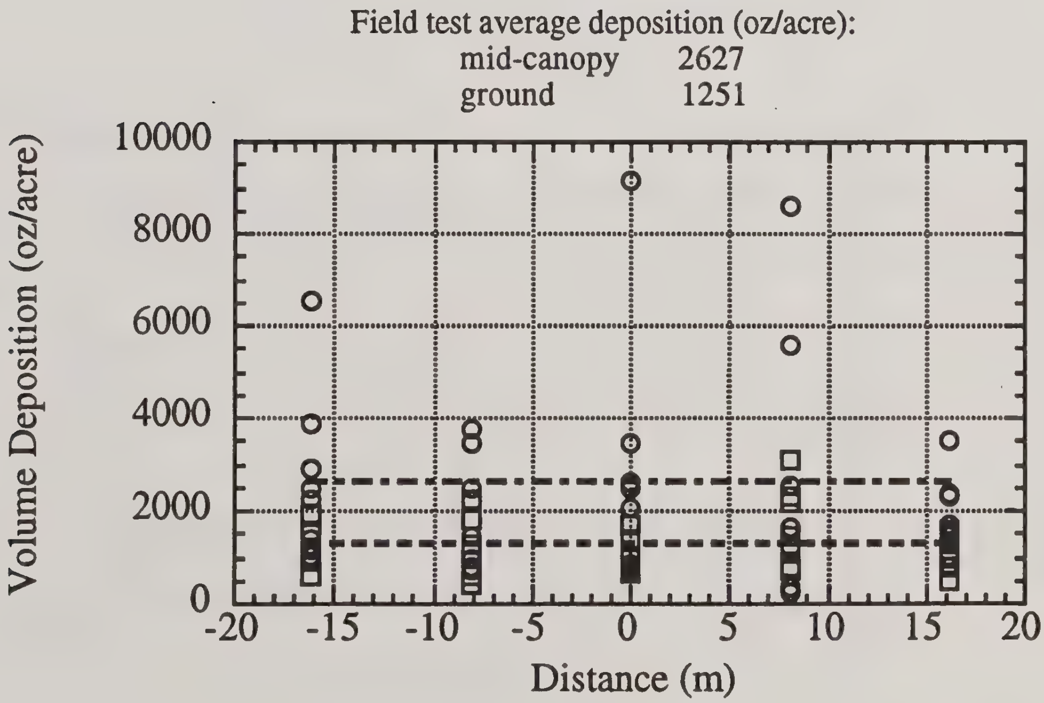
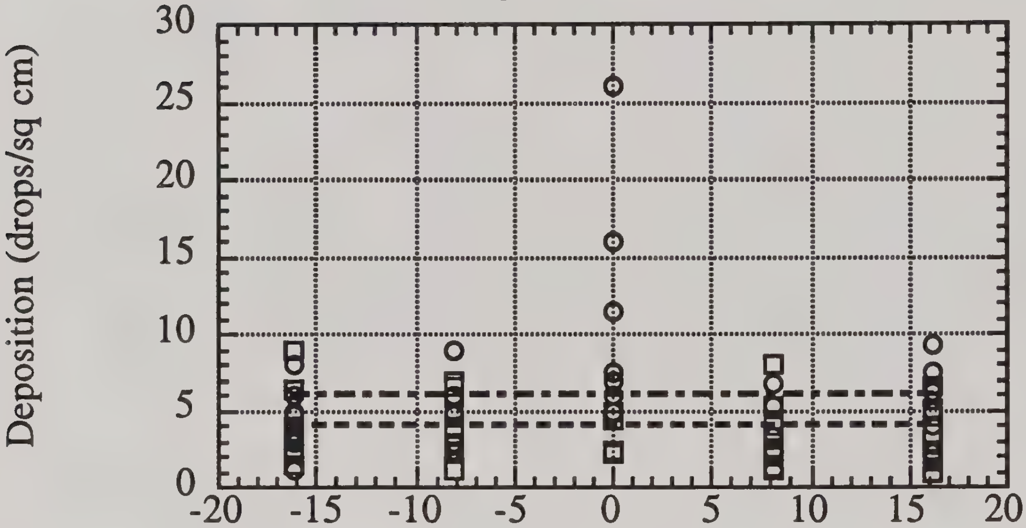


Figure 8: March 8, Phase C field test deposition in drops per square cm and ounces per acre for beverage can collectors at mid-canopy (circles) and ground (squares). Average values for mid-canopy and ground are shown by dashed lines and specified above each plot.

Field test average deposition (drops/sq cm):
mid-canopy 6
ground 4



Field test average deposition (oz/acre):
mid-canopy 11.4
ground 8.2

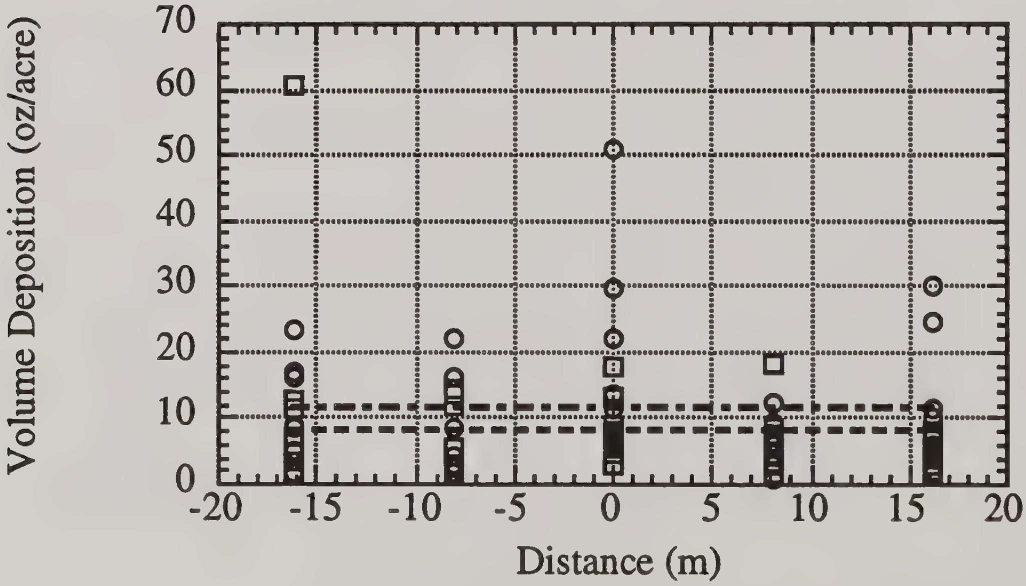


Figure 9: March 8, Phase D field test deposition in drops per square cm and ounces per acre for beverage can collectors at mid-canopy (circles) and ground (squares). Average values for mid-canopy and ground are shown by dashed lines and specified above each plot.

Table 5: Average Field Test Deposition in the Canopy (Top of Can Data Only)

DROPS PER SQUARE CENTIMETER

Date/ Phase	Canopy East	Canopy West	Canopy All[1]	Ground East	Ground West	Ground All[1]	ALL (Canopy + Ground)
February 22							
B	23	26	24	16	14	15	20
C	62	57	59	39	40	39	49
D	6	6	6	4	6	5	6
March 8							
B	26	19	22	16	14	15	18
C	51	55	53	41	43	42	48
D	7	5	6	4	4	4	5

OUNCES PER ACRE

Date/ Phase	Canopy East	Canopy West	Canopy All*	Ground East	Ground West	Ground All*	ALL (Canopy + Ground)
February 22							
B	1095	1224	1160	822	944	883	1022
C	2742	2700	2721	2543	2000	2271	2496
D	18	20	19	14	15	14	17
March 8							
B	828	788	808	650	695	672	740
C	2560	2694	2627	1253	1249	1251	1940
D	14	8	11	7	8	8	9

1. "Canopy" refers to the mid-canopy elevation, 4.6 meters. "Ground" elevation is 0.46 meters. These values are shown in Figures 4 through 9.

Table 6: Average Volume Median Diameter (VMD) and Number Median Diameter (NMD) Observed on the Top of Can Samplers

	VMD (µm)		NMD (µm)	
Date/ Phase	Canopy	Ground	Canopy	Ground
February 22				
B	741	676	152	149
C	798	637	140	141
D	193	162	68	65
March 8				
B	702	606	148	145
C	644	519	149	144
D	166	144	64	63

3. FSCBG Simulation of Canopy Deposition Data

Aircraft and spray system variables, canopy characteristics, and average meteorological conditions for each phase of the 1994 Hennigan trials were used to simulate field test deposition data using the FSCBG aerial spray model, described in the introduction. The operation of FSCBG is further described in Teske and Curbishley (1991, 1994).

Table 7 shows the aircraft and spray system variables for the two aircraft used in each phase of the trials. Drop distribution data for the CP nozzles used in Phases B and C and for the Micronair atomizers used in Phase D are given in Tables 8 and 9, respectively. Note that both distributions are approximations of the actual spray systems used in the trials. Drop distribution data for the CP nozzles were not available, and the data shown in Table 7 were generated using mean drop diameter data from a different orifice size and flow rate, and for a different spray formulation, than those of the Hennigan trials (N.B. Akesson, private communication, 1992).

As previously mentioned, meteorological data available for the trials were averages over the spray times of each phase. Because the spray was released close to the canopy, it was affected mainly by the canopy meteorology and wake forces of the aircraft interacting with the canopy and the ground. Table 3 shows that the meteorological conditions in the canopy were relatively quiescent on March 8. On February 22 there was apparently slightly more turbulence in the canopy because of the elevated wind speeds.

The presence of a canopy removes spray material by permitting its impaction on vegetation. The probability that a drop will penetrate a canopy depends on the total number and size of vegetative elements encountered, droplet specific gravity, drop size, fall velocity and aircraft wake turbulence. Since the orientation of the vegetative elements is assumed to be random, the probability of penetration for a given path length will be the same for all directions. Teske et al. (1993a) describes the canopy penetration model used in FSCBG in detail. The probability of penetration, the probability that a drop traversing along its trajectory will penetrate a typical single tree envelope, is a value that is either assigned according to tree type based on foliage density and envelope dimensions, or determined from optical measurements as a function of sun incidence angle. For this report, the probability of penetration of the almond trees in the popcorn stage was inferred as 0.4 and in the blossom petal fall stage as 0.3. These numbers are based on previous studies of broadleaf canopies (Teske et al., 1993a and J.W. Barry, private communication, 1995), and model sensitivity.

Although the exact position of the spray aircraft during the trials is unknown, the aircraft always passed within a swath width (12.5 meters) of a given set of sample trees. Thus, to simulate the amount of spray descending into the canopy in the area of the sample trees, the spray aircraft was modeled to fly in 12.5 meter swaths on either side of the sample trees in a North-South, South-North direction. Discrete receptors for deposition were placed in the center swath, at both elevations within the canopy, for the entire width of the swath, perpendicular to the lines of flight. The deposition levels predicted in this manner indicate a range of deposition that would be expected over the sample trees within a

12.5 meter swath. This range can then be compared to the average values of deposition measured during the trials.

During modeling of the trials, it became apparent that the FSCBG predicted deposition levels (drops as well as volume) were different from the levels recorded in the field. The worst correlation with field data was for those trials modeled with the CP nozzles (Phases B and C). As mentioned previously, the drop size distribution used to model the CP spray system is not necessarily representative of the actual CP spray system in use during the trials. FSCBG correlation with the data from Phase D, which used a Micronair spray system, was much better. Accordingly, data from February 22, Phase D, were used for a sensitivity study of the canopy and receptor variables used to model field conditions. Of particular interest was the probability of penetration at each tree growth stage.

Figure 10 shows the average FSCBG predicted deposition over a 12.5 meter swath for a range of probability of penetration from 0.2 to 1.0. The greater the probability of penetration, the more drops should be penetrating to any elevation in the canopy; thus, the predicted average deposition at each elevation increases with increasing probability of penetration. Furthermore, as the probability of penetration increases, more of the spray penetrates to the ground, and deposition near the ground begins to exceed deposition in mid-canopy. As indicated, the predictions shown in this Figure were generated using the Micronair spray system of Phase D, with meteorological data from February 22.

The average field test deposition levels at each canopy elevation (February 22, Phase D) are noted on Figure 10 as desired deposition levels. A probability of penetration of approximately 0.55 (with the spray system and meteorology specified) will result in a predicted deposition level of 14 ounces per acre on the tops of the ground can samplers. Note that, with the spray system as defined, it is not possible to match desired levels of deposition for both drops and volume with any value of probability of penetration. This may indicate that the drop size distribution used for the Micronair spray system is not the same as the actual spray entering the canopy. A similar sensitivity study was done for the CP nozzle spray system, with similar results: it was not possible to achieve good correlation of both drop and mass deposition at a specific probability of penetration.

A probability of penetration of 0.4 for this stage of tree growth (popcorn) seems to be the best compromise for correct modeling of the canopy. At this probability of penetration, FSCBG under predicts the volume of deposition observed for each spray system by about half, but predicts about twice the number of drops deposited.

Several other canopy and receptor variables were also examined. Changing the tree shape and the element size had very little effect on the average levels of deposition predicted over the swath. The density of trees in the canopy, defined as the number of stems per acre, also has little effect on the average deposition levels predicted.

Four types of discrete receptors can be defined in FSCBG: flat cards with 100% collection efficiency; flat cards of characteristic width, with a lower collection efficiency; cylinders with specified X, Y, and Z outward normals and diameter; and spheres. To explore the effect of the collection efficiency of the discrete receptors, the type and size of the receptors were varied. The best match to field test deposition levels is a can top

receptor (whose collection efficiency is determined internally by FSCBG based on the work of Golovin and Putnam, 1962).

Despite all efforts to model the canopy and receptors to best match the field test data, average FSCBG predictions of deposition over the swath are still different from average field test levels. However, it is encouraging that all averages of field test deposition data fall within FSCBG predicted deposition levels across the swath except the average volume deposition at mid-canopy for February 22, Phase B. The results presented here are therefore considered the best compromise we can make with available knowledge about the field study, canopy structure, and the drop size distributions for the spray systems used.

Figure 11 shows the average drops deposited and the average volume deposition at the mid-canopy elevation as measured in the field, February 22, Phase B, compared to the corresponding FSCBG prediction of the range of deposition expected. The average of the field test data is shown as a dashed line, and the average of the FSCBG predicted deposition over the swath is shown as a solid line. Note that the FSCBG prediction over the swath shows significant scatter in both drops and volume deposited (receptor locations are uniformly distributed across the swath). Some of this scatter is probably due to wind just above and within the canopy. Also, the drop size distribution used to model the CP nozzles used in Phases B and C is extensively defined and includes many small drop sizes (see Table 8). Small drops are particularly susceptible to turbulence in the canopy. Finally, deposition across the swath is affected by spray from adjacent swaths (the model is simulating ten flight lines on either side of the sample tree line, alternating in direction, north-to-south and south-to-north, as flown during the field trials).

As noted above, the field test average volume deposition for this application (February 22, Phase B) does not fall within the FSCBG predicted range of deposition over the swath. The predicted number of drops deposited at mid-canopy by the CP nozzles is larger than the number of drops actually measured at this elevation, but is well within the predicted range of deposition.

Figures 12 through 16 show the predicted deposition at mid-canopy over a 12.5 meter swath for the remaining phases of application on both days of testing. Figures 17 through 22 show the corresponding predicted and field test average deposition at ground level (0.46 meters). Average predicted deposition over the swath for all phases of testing and at both elevations is shown in Table 10. As noted earlier, FSCBG consistently under predicts the average volume deposition and over predicts the average drop deposition.

Another source of scatter in the FSCBG predicted deposition is apparent when comparing predictions from different phases of application, representing different spray systems. Predicted deposition for the Micronair atomizers (Phase D) is much smoother than predicted deposition for the nozzles (Phases B and C). The spray system used in Phase B had only twenty nozzles along the spray boom, and shows more scatter across the swath than the other spray system used.

Figures 23 compares the field test average deposition values from Table 5 with the FSCBG average predicted deposition values from Table 10. All average values calculated (at mid-canopy and at ground elevation) are plotted. Correlation of predicted and observed average deposition shows a least squares slope of 0.49 (with $R^2 = 0.93$) for volume

deposition and a least squares slope of 2.25 (with $R^2 = 0.93$) for the number of drops deposited. When only the Phase D trials are considered, correlation of the observed and predicted averages improves. These results are in keeping with the previous discussion of inaccuracies in the modeling of the CP nozzle spray system.

Table 11 shows the average observed VMD and NMD for each application of spray (presented previously in Table 6) and the corresponding predicted VMD and NMD for each phase. FSCBG underpredicts the VMD for the nozzle spray systems (Phases B and C), but predicts both VMD and NMD for the Micronair atomizers (Phase D) well.

Table 7: Aircraft Characteristics for the Hennigan Trials

Aircraft Type	Bell Jet Ranger 206	Schweizer Ag Cat
Weight (kg)	932	2347
Rotor Diameter (m)	10.2	
Wing Span (m)		12.9
Planform Area (sq m)		36.7
Drag Coefficient		0.10
Propeller Radius (m)		1.34
Propeller Efficiency		0.80
Blade RPM	304	2300
Number of Nozzles/Atomizers	20 (Phase B) 60 (Phase C)	6 (Phase D)
Nozzle Type Assumed	CP Plastic	Micronair
Flow Rate (gal/min)	13.6 (Phase B) 40.9 (Phase C)	4.6 (Phase D)
Spraying Speed (m/sec)	13.4 (Phases B and C)	49.2 (Phase D)

Table 8: Drop Size Distribution Assumed for Phases B and C

Drop Diameter (micrometers)	Mass Fraction	Drop Diameter (micrometers)	Mass Fraction
10.77	.00343	152.79	.04536
16.93	.00197	177.84	.05884
19.39	.00102	205.84	.07005
22.49	.00130	238.45	.08407
26.05	.00165	276.48	.09574
30.21	.00216	320.60	.1030
35.01	.00280	372.18	.1041
40.57	.00368	430.74	.09303
47.03	.00488	498.91	.07752
54.50	.00648	578.54	.05717
63.16	.00865	670.72	.03544
73.23	.01161	777.39	.01799
84.85	.01542	900.61	.00733
98.12	.02017	1044.42	.00244
113.71	.02692	1210.66	.00066
131.73	.03500	1403.04	.00016

			1.0000

The distribution above is for CP plastic nozzles spraying water, with an orifice of 0.17 in, at 40 psi, 110 mph (N.B. Akesson private communication, 1992). The CP nozzles in the field trials had an orifice of 0.068 at 40 psi and 30 mph; the material sprayed was Foray 48B, undiluted. The distribution used here was the most representative one available.

Table 9: Drop Size Distribution Assumed for Phase D

Drop Diameter (micrometers)	Mass Fraction
56.00	.1399
89.00	.2431
122.00	.2769
154.00	.1905
187.00	.09530
219.00	.03280
252.00	.01170
284.00	.00670
318.00	.00210
351.00	.00090
382.00	.00010

	1.0000

The distribution above is for Micronair AU5000 atomizers, spraying undiluted Foray 48B, at 8170 RPM, 110 mph. These were the atomizers used in the field trials, with the correct formulation and at the right speed. RPM setting during the field trials was not specified; however, the atomization was very fine (J.W. Barry, private communication, 1995).

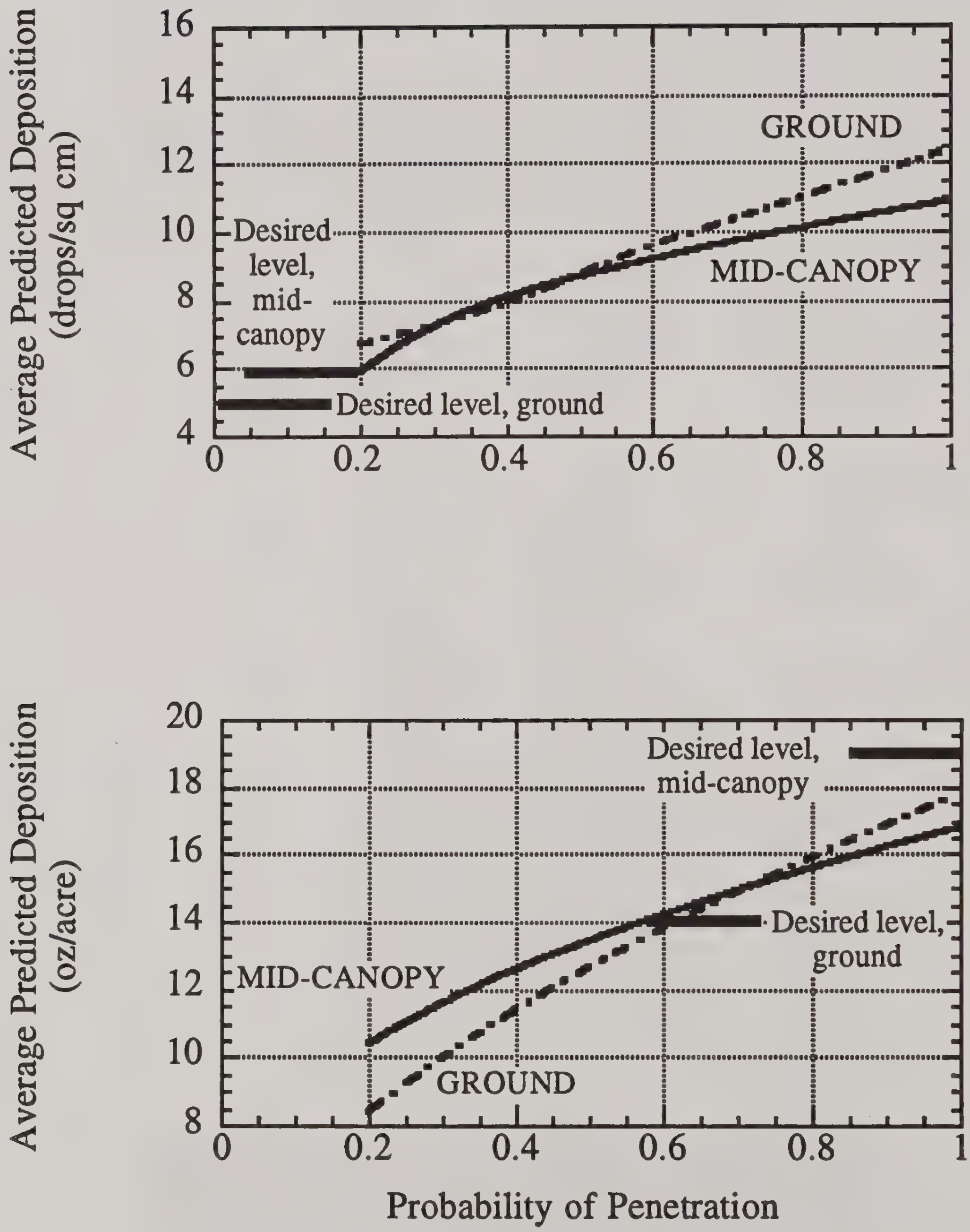
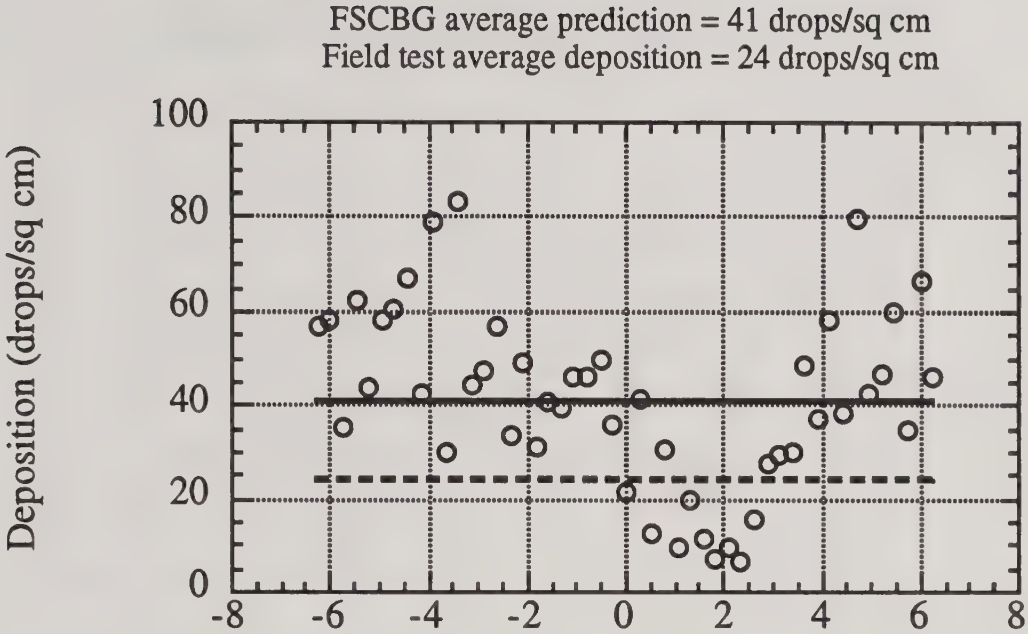


Figure 10: Probability of penetration sensitivity study, showing average predicted deposition (drops and volume) as a function of probability of penetration. Desired levels shown are from field test data, February 22, Phase D.



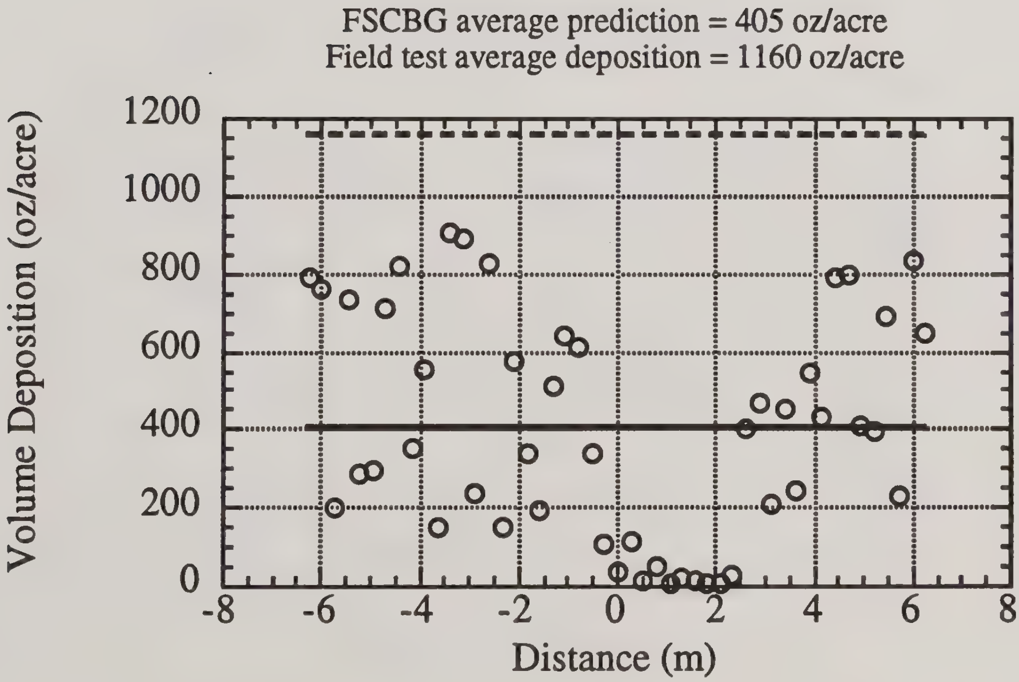


Figure 11: February 22, Phase B FSCBG predicted deposition over a 12.5 meter swath, mid-canopy elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.

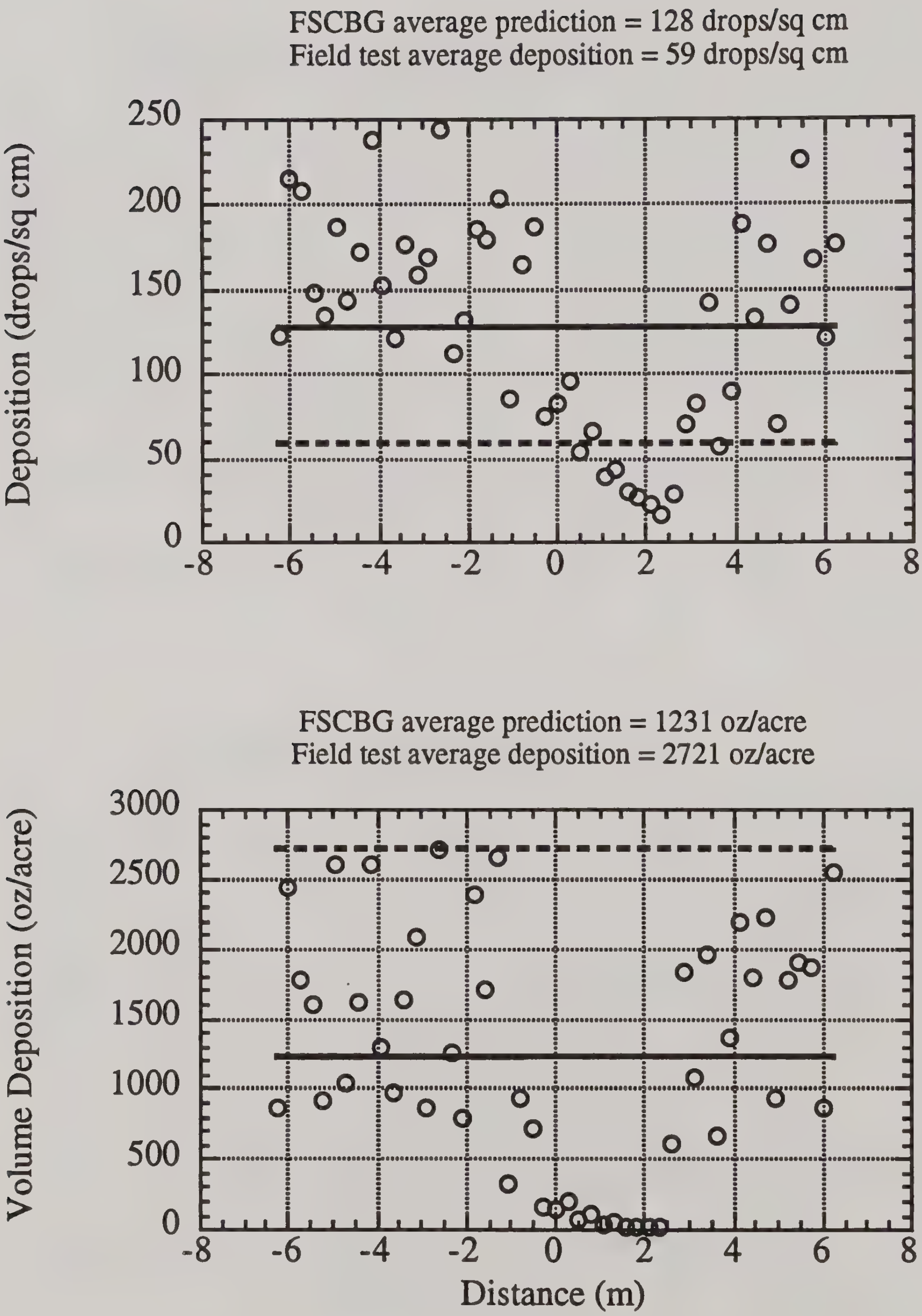
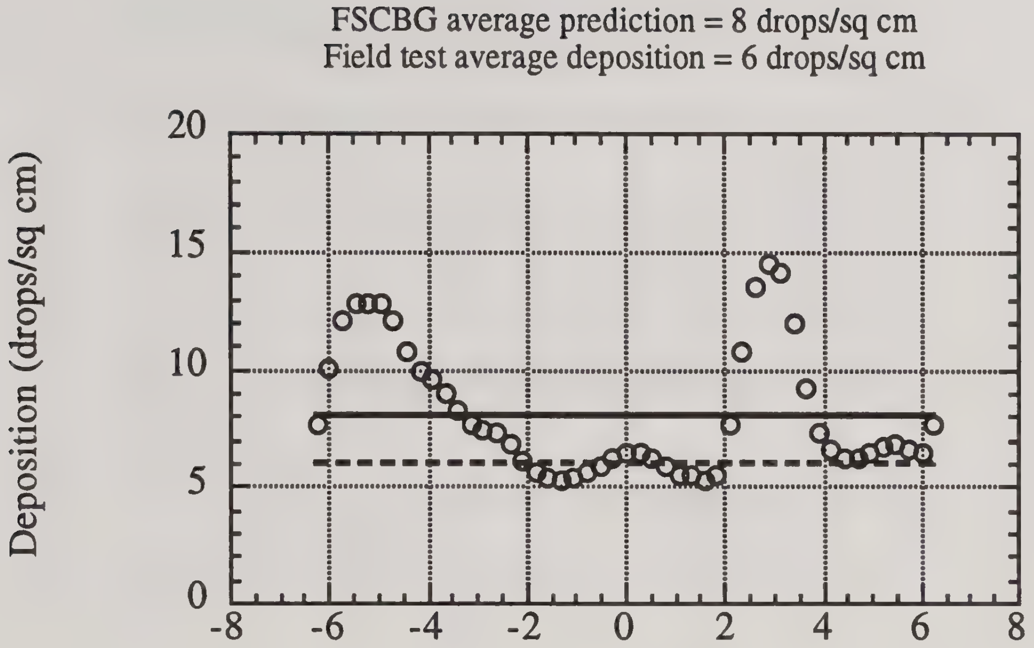


Figure 12: February 22, Phase C FSCBG predicted deposition over a 12.5 meter swath, mid-canopy elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



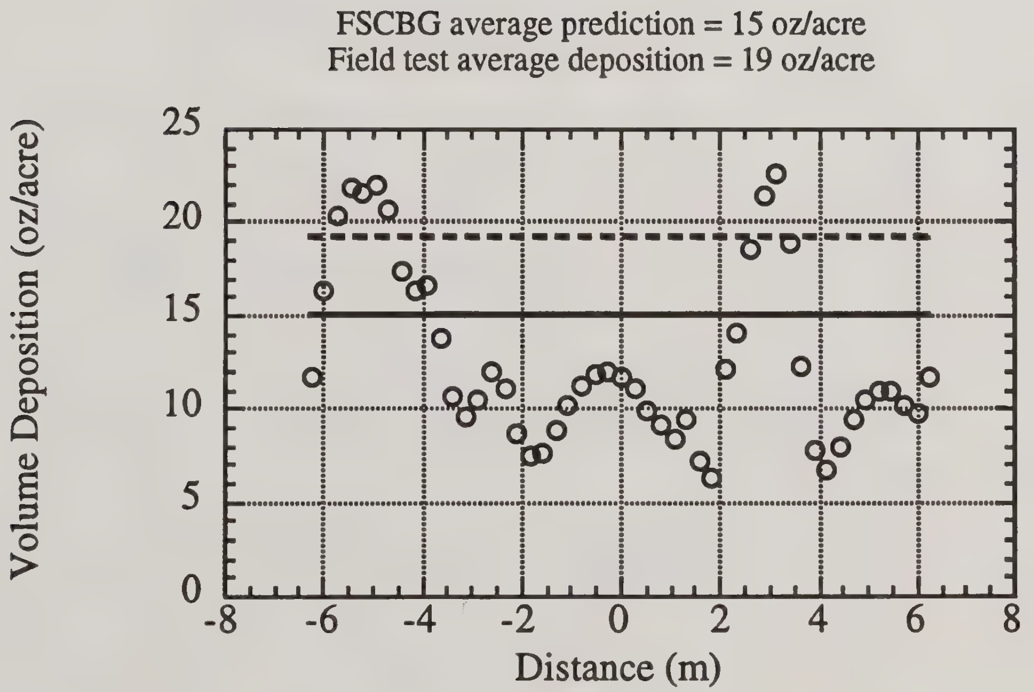
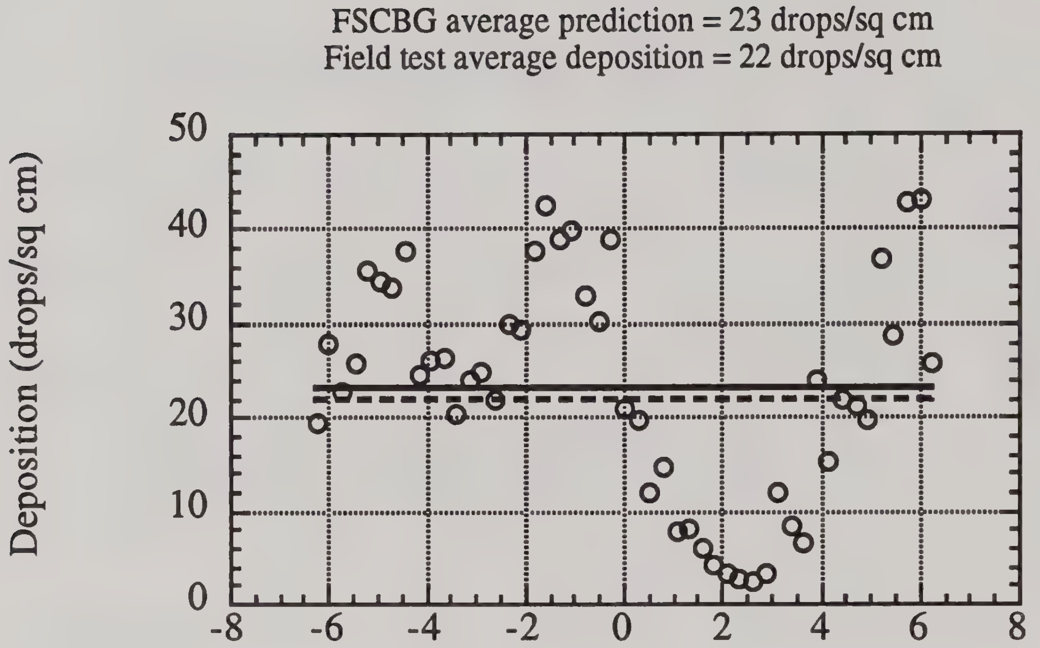


Figure 13: February 22, Phase D FSCBG predicted deposition over a 12.5 meter swath, mid-canopy elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



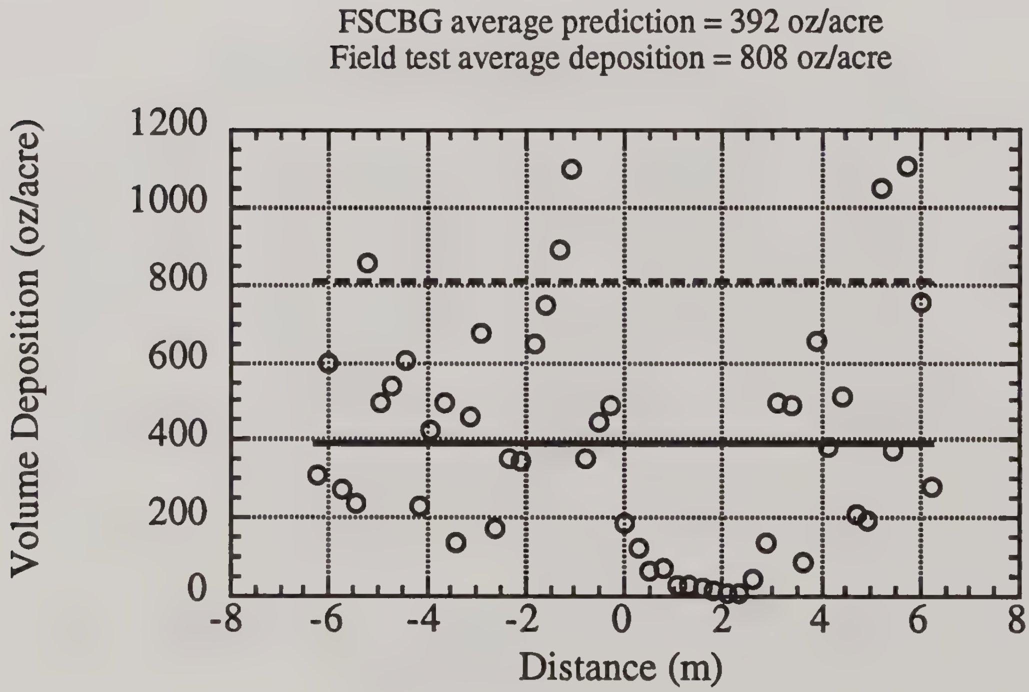
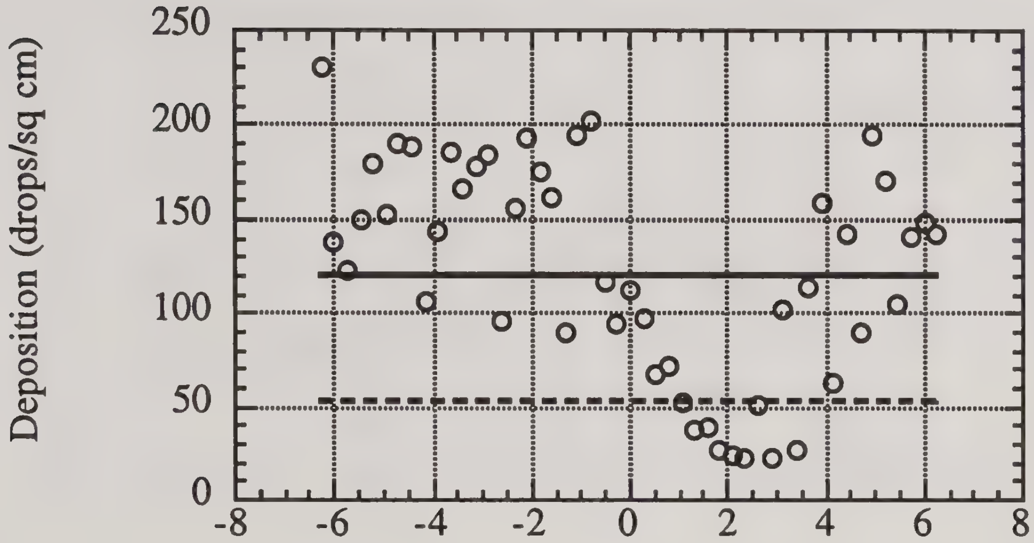


Figure 14: March 8, Phase B FSCBG predicted deposition over a 12.5 meter swath, mid-canopy elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.

FSCBG average prediction = 120 drops/sq cm
Field test average deposition = 53 drops/sq cm



FSCBG average prediction = 1260 oz/acre
Field test average deposition = 2721 oz/acre

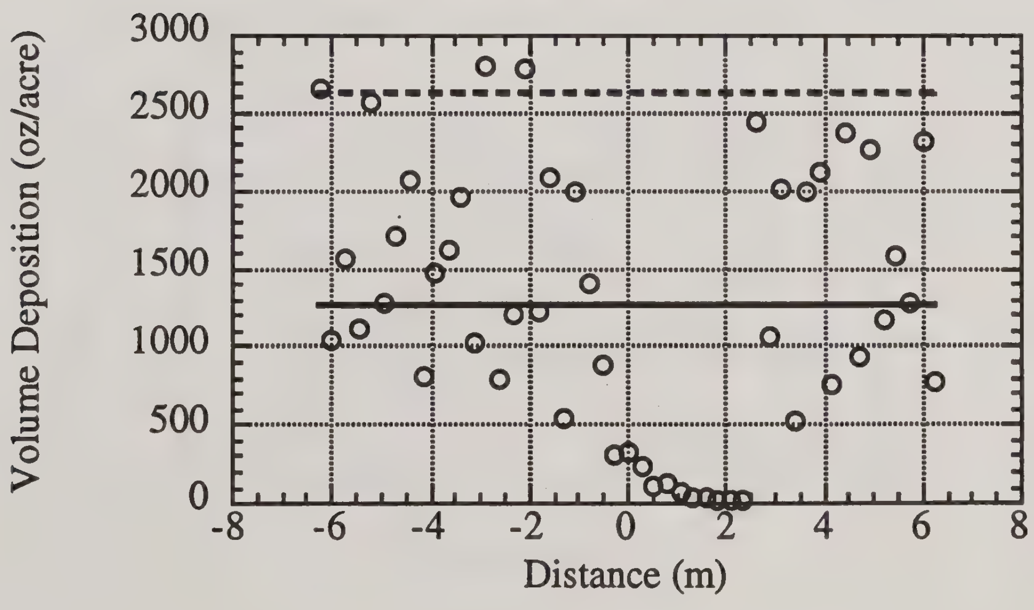
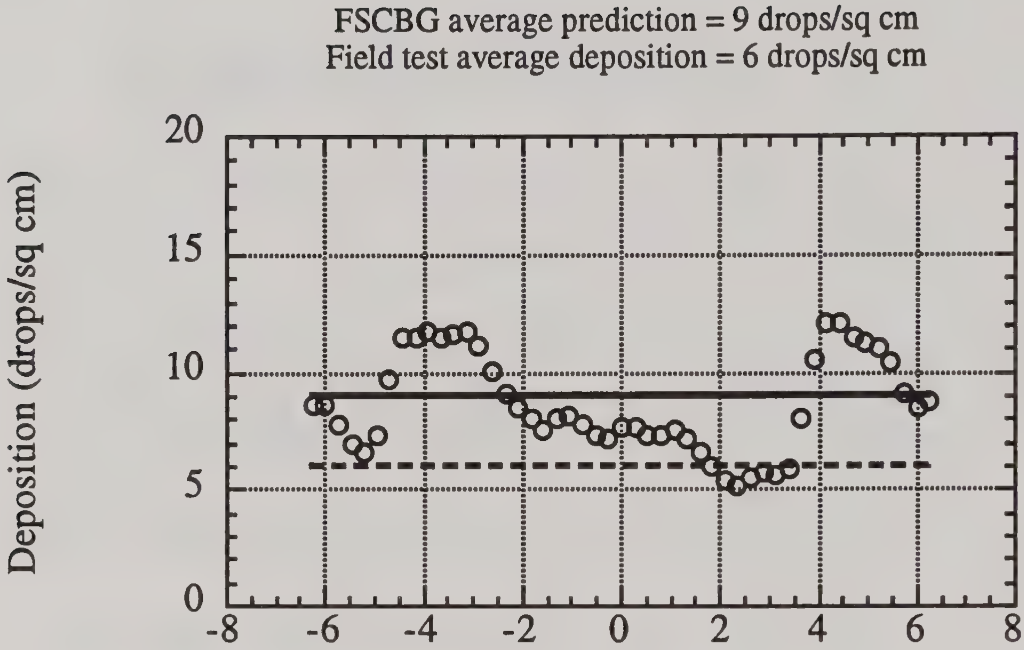


Figure 15: March 8, Phase C FSCBG predicted deposition over a 12.5 meter swath, mid-canopy elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



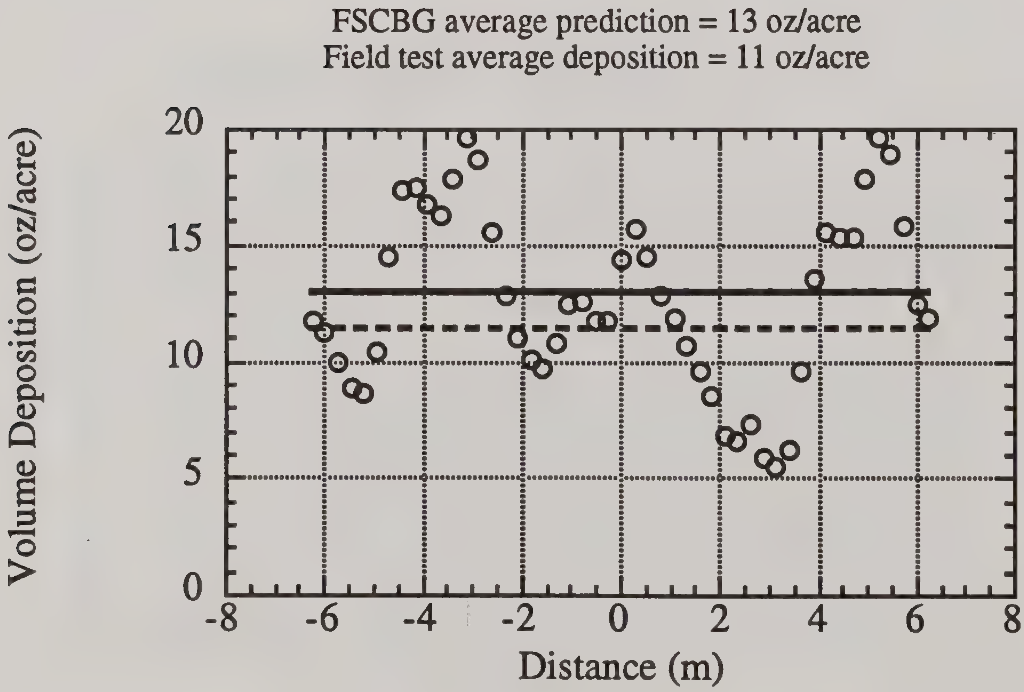
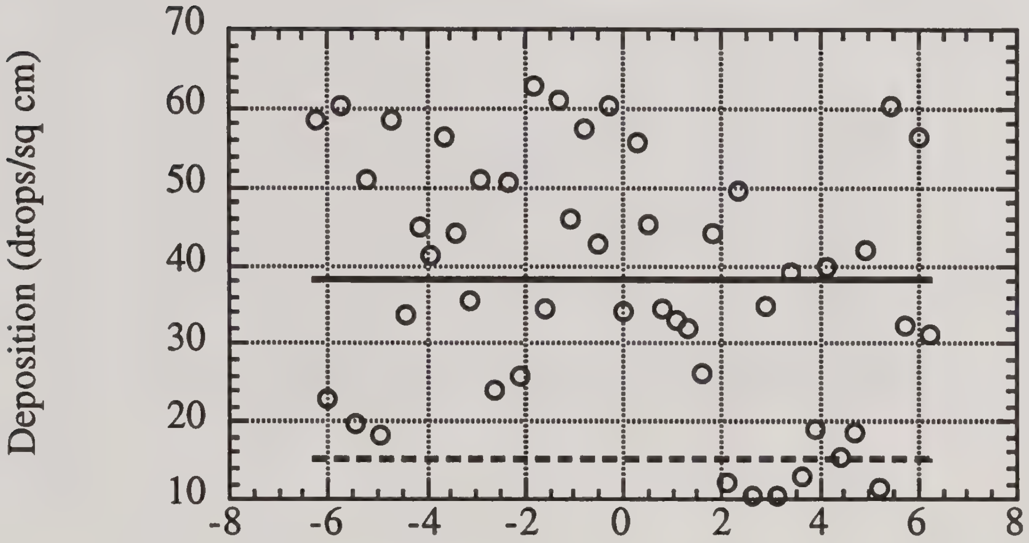


Figure 16: March 8, Phase D FSCBG predicted deposition over a 12.5 meter swath, mid-canopy elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.

FSCBG average prediction = 38 drops/sq cm
Field test average deposition = 15 drops/sq cm



FSCBG average prediction = 361 oz/acre
Field test average deposition = 883 oz/acre

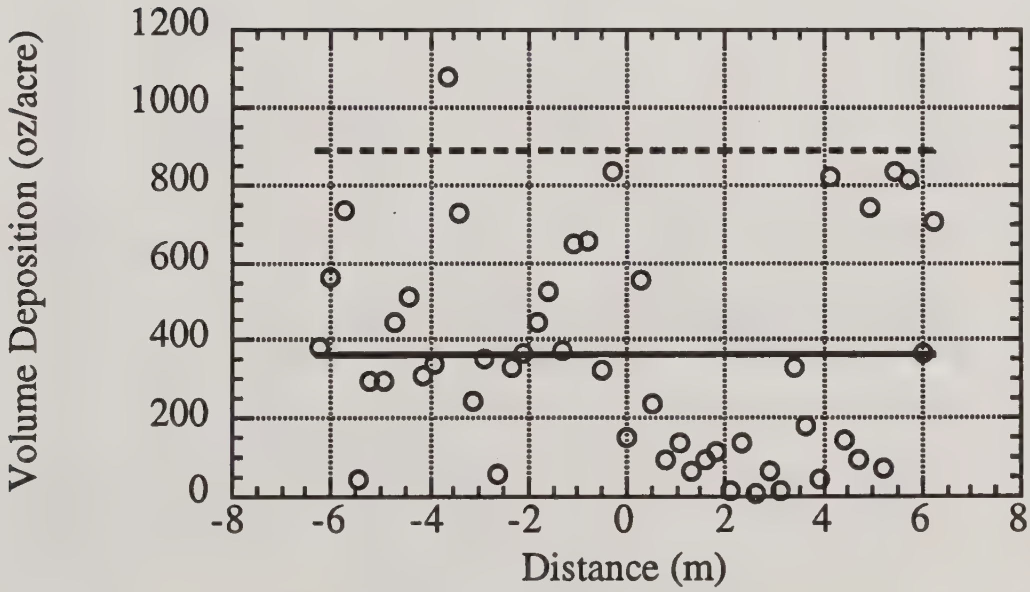
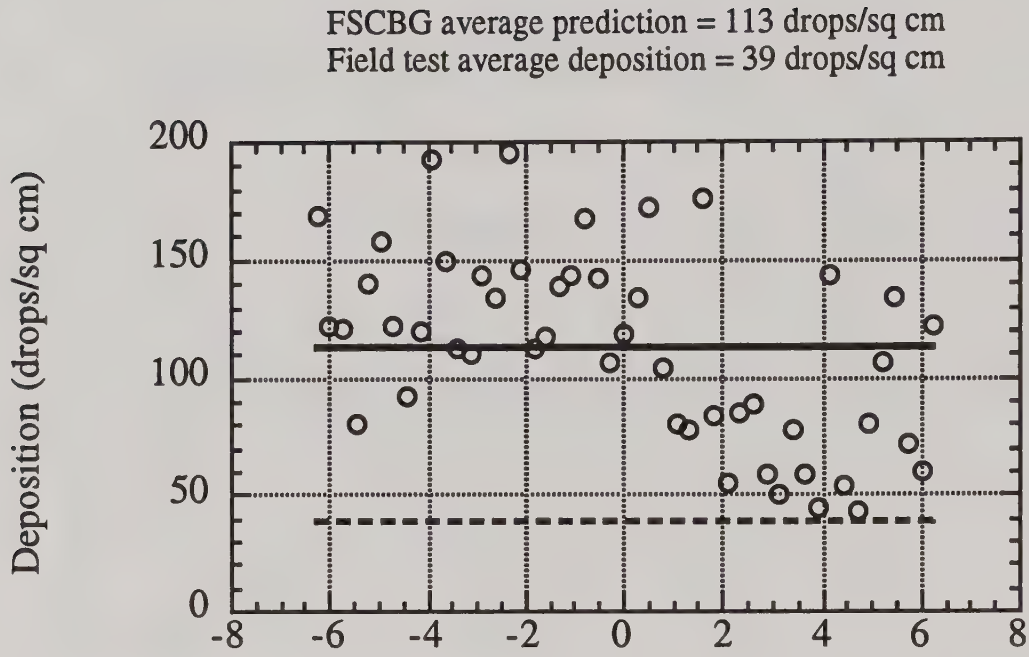


Figure 17: February 22, Phase B FSCBG predicted deposition over a 12.5 meter swath, ground elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



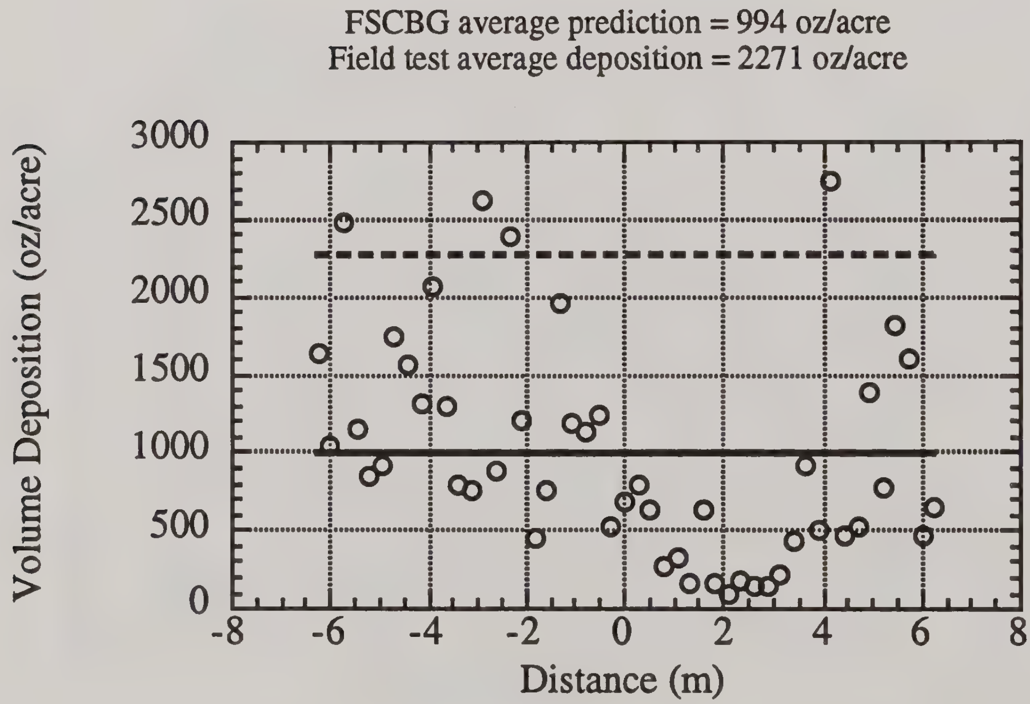
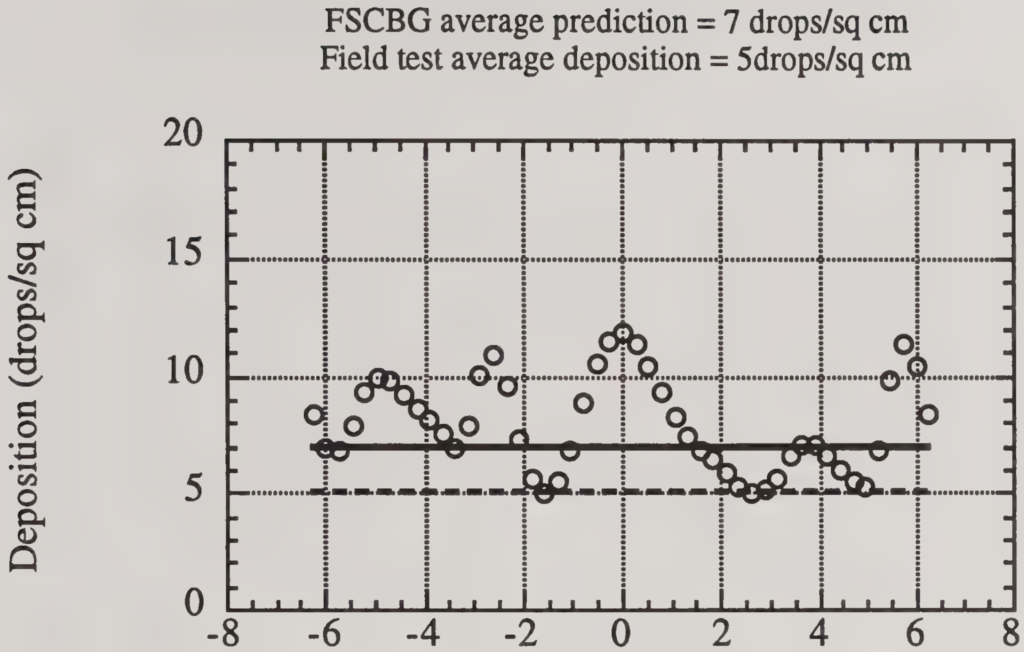


Figure 18: February 22, Phase C FSCBG predicted deposition over a 12.5 meter swath, ground elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



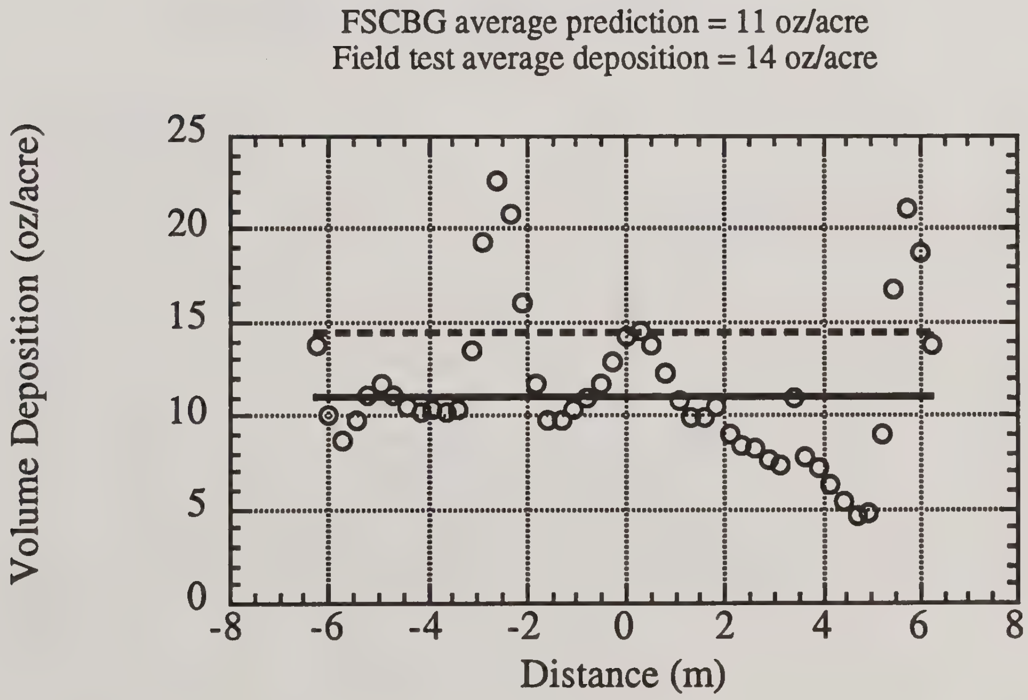
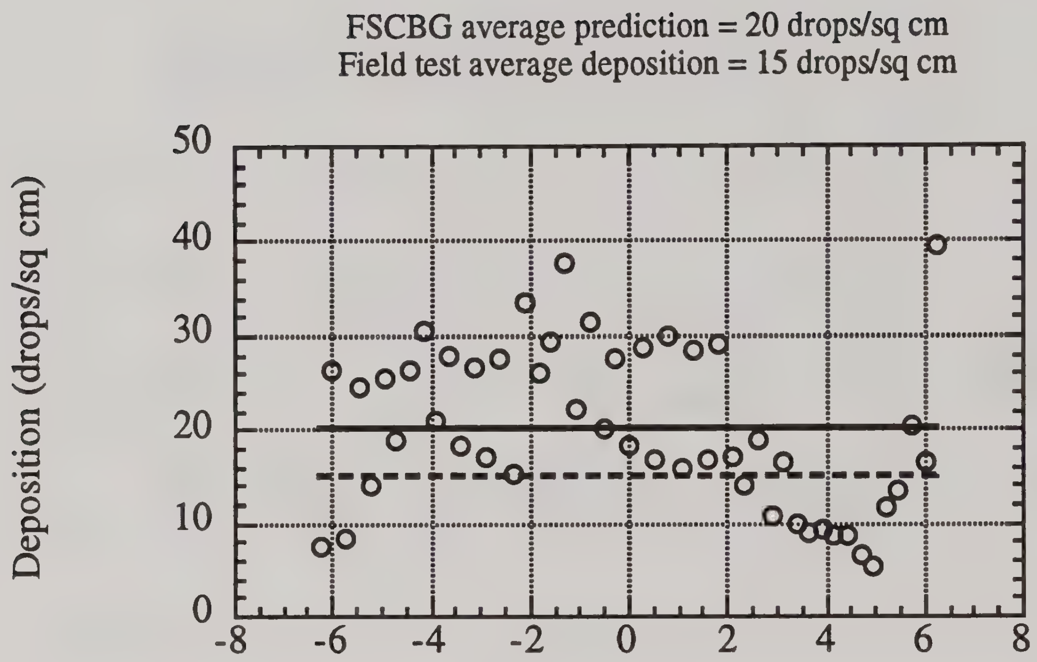


Figure 19: February 22, Phase D FSCBG predicted deposition over a 12.5 meter swath, ground elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



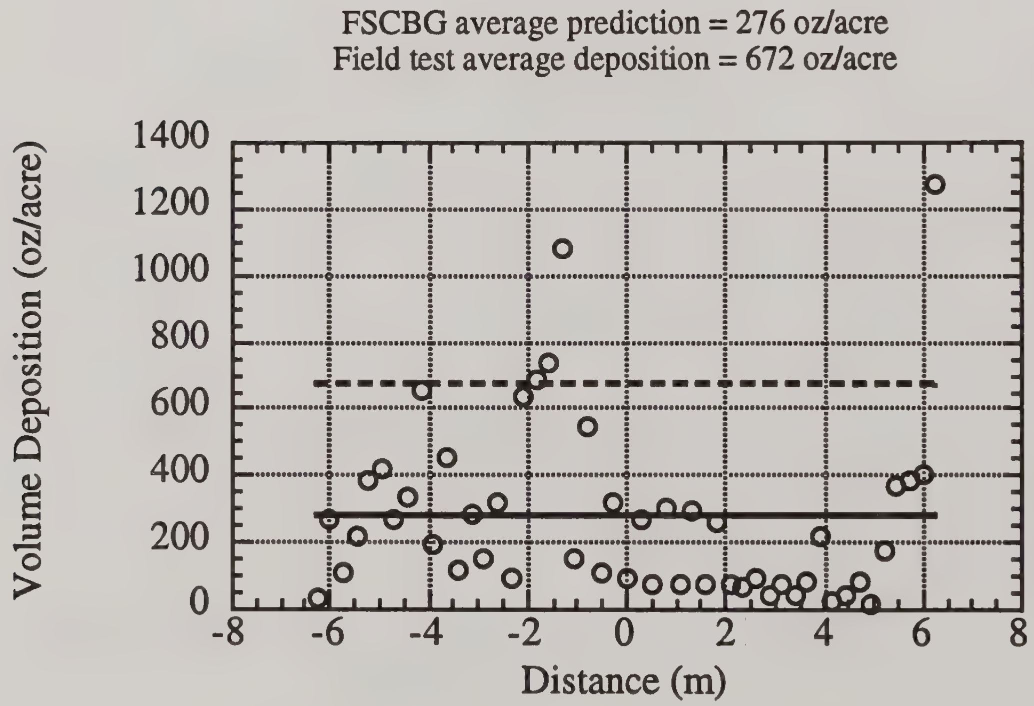
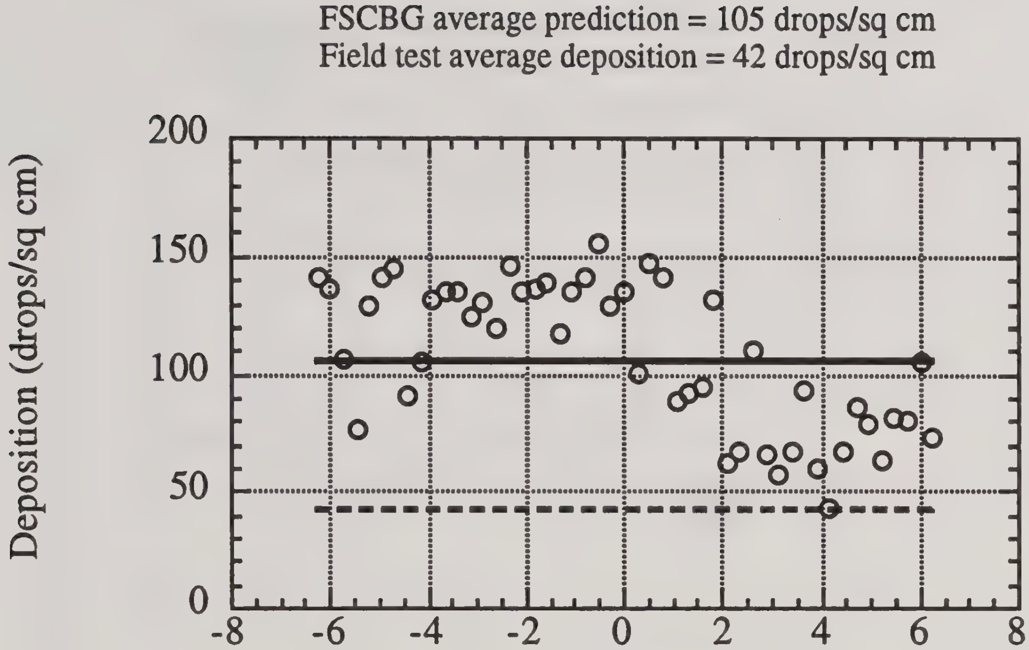


Figure 20: March 8, Phase B FSCBG predicted deposition over a 12.5 meter swath, ground elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



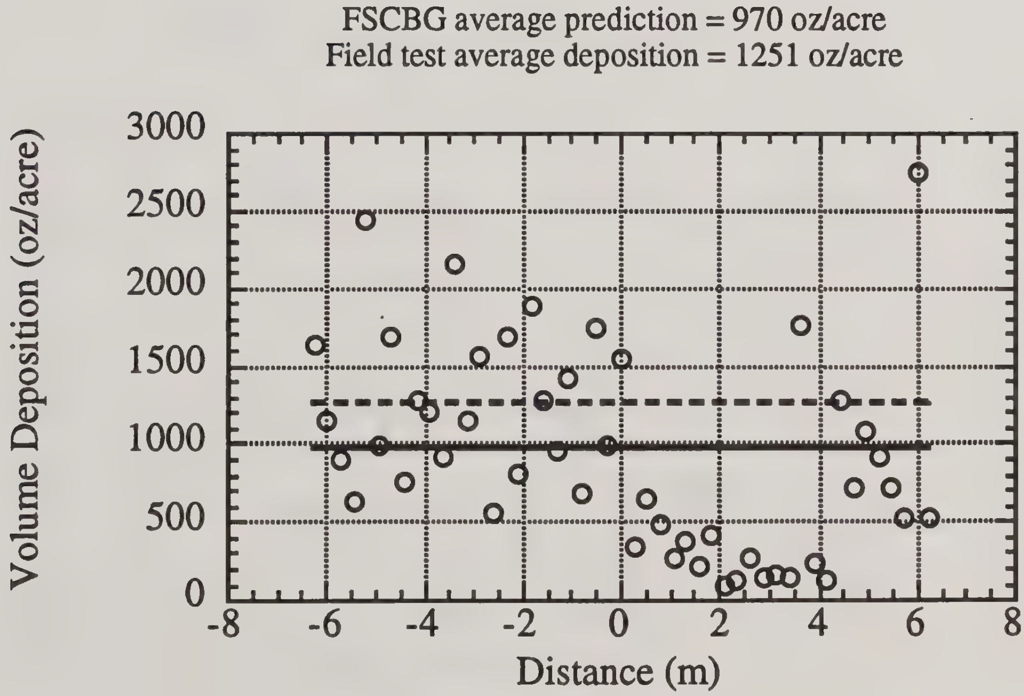
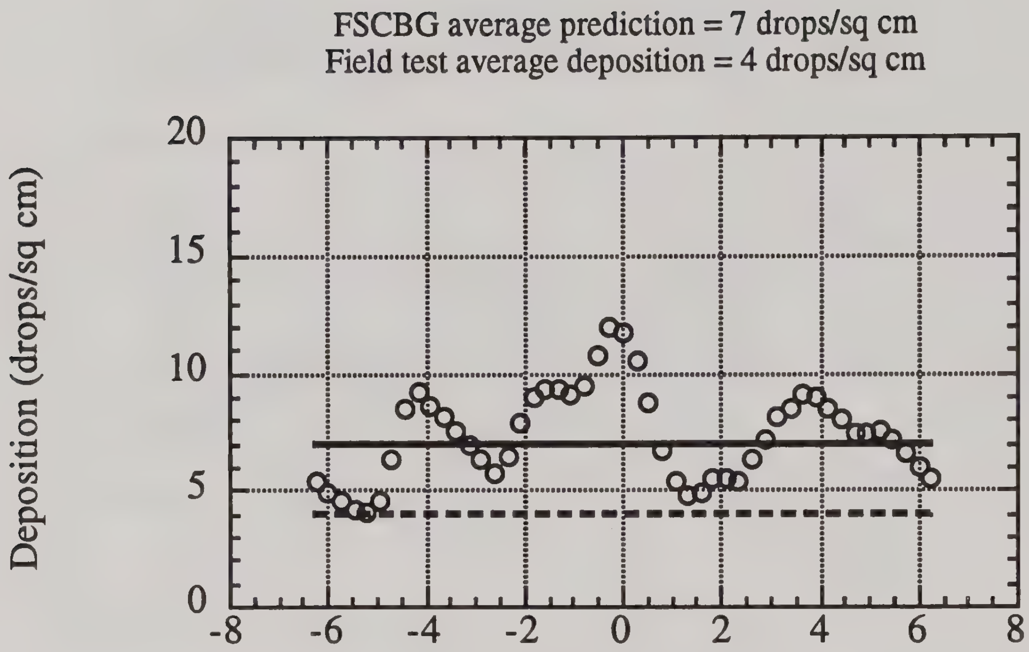


Figure 21: March 8, Phase C FSCBG predicted deposition over a 12.5 meter swath, ground elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.



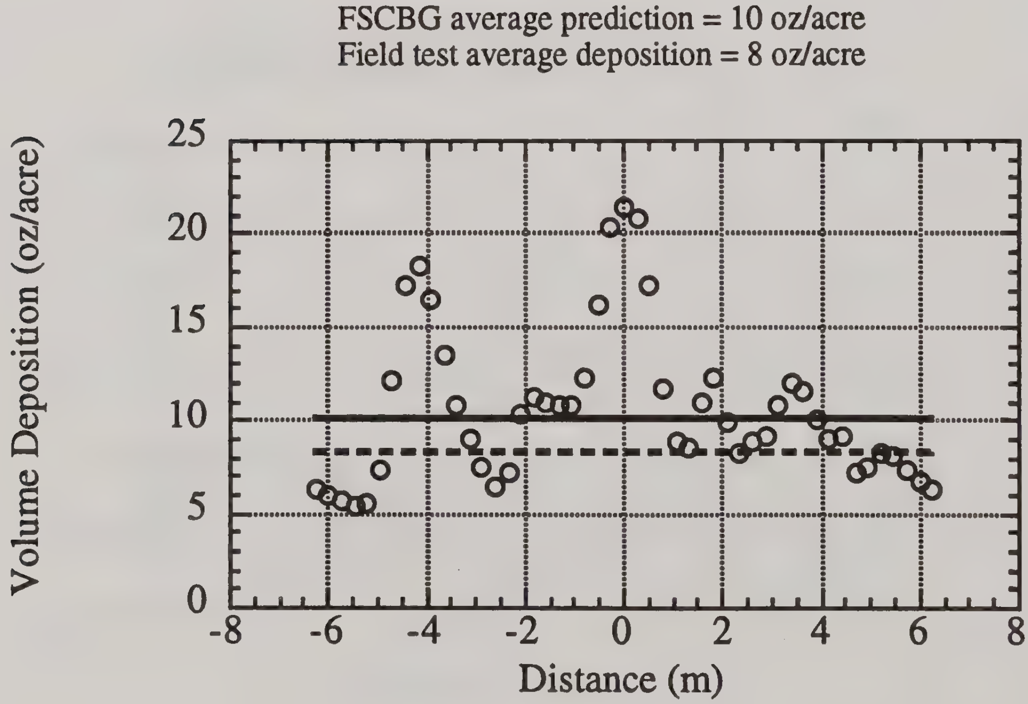


Figure 22: March 8, Phase D FSCBG predicted deposition over a 12.5 meter swath, ground elevation, compared to the average field test deposition. FSCBG predictions are shown as open circles. FSCBG average predictions (solid lines) and field test average values (dashed lines) are specified above each plot.

Table 10: Average FSCBG Predicted Deposition in the Canopy

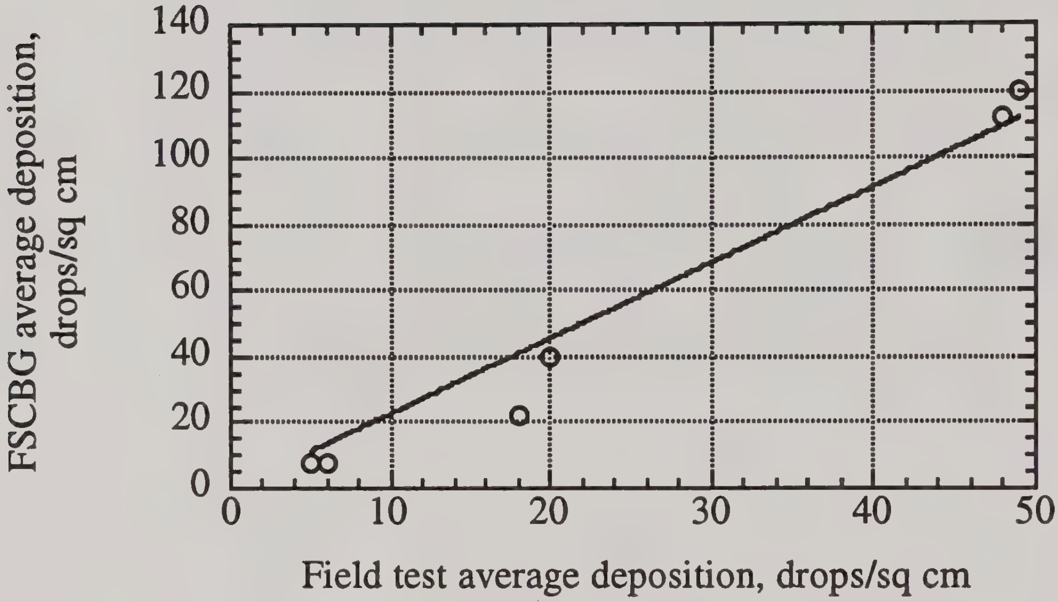
DROPS PER SQUARE CENTIMETER

Date/ Phase	Canopy	Ground	ALL[1]
February 22			
B	41	38	40
C	128	113	120
D	8	7	8
March 8			
B	23	20	22
C	120	105	112
D	9	7	8

OUNCES PER ACRE

Date/ Phase	Canopy	Ground	ALL[1]
February 22			
B	405	361	383
C	1231	994	1112
D	15	11	13
March 8			
B	392	276	334
C	1260	950	1105
D	13	10	12

1. "Canopy" refers to mid-canopy elevation, 4.6 meters. "Ground" refers to 0.46 meters. "ALL" is the average of canopy and ground.



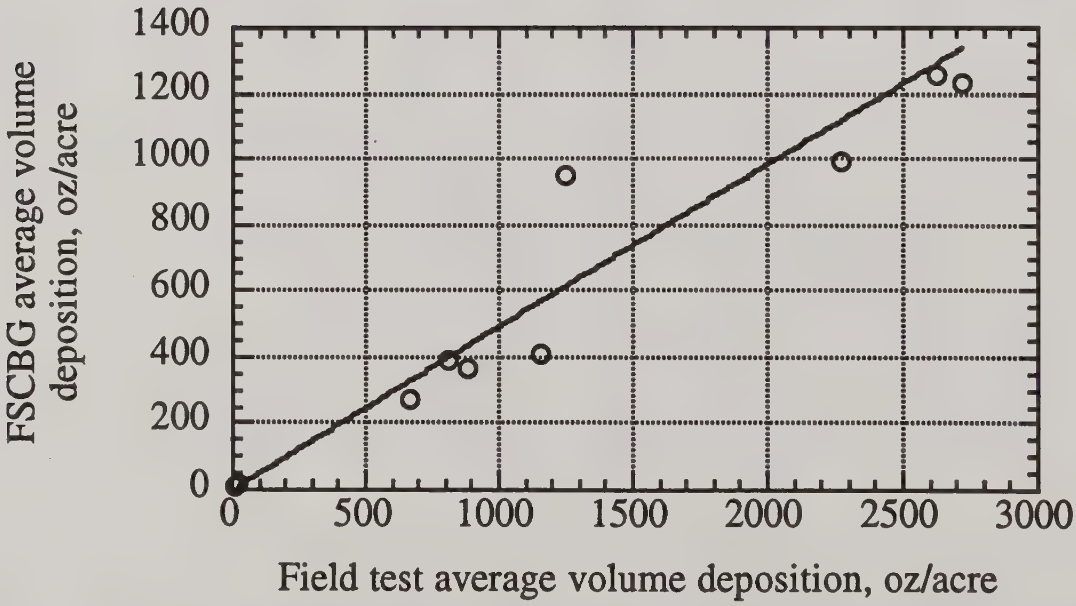


Figure 23: Predicted and field test average deposition for drops (top) and volume (bottom).
For drops, least squares slope = 2.25 with $R^2 = 0.93$.
For volume, least squares slope = 0.49 with $R^2 = 0.93$.

Table 11: Average Observed Droplet Size Data (VMD and NMD) and Predicted Droplet Size Data

	VMD (μm)				NMD (μm)			
	Canopy		Ground		Canopy		Ground	
Date/ Phase	Field Test	Predicted	Field Test	Predicted	Field Test	Predicted	Field Test	Predicted
February 22								
B	741	525	676	429	152	165	149	139
C	798	430	637	388	140	150	141	144
D	193	175	162	160	68	85	65	74
March 8								
B	702	580	606	517	148	150	145	133
C	644	490	518	401	149	151	144	142
D	166	139	144	130	64	62	63	60

4. Evaluation of Downwind Drift Data

On the second day of aerial application of Phases B, C and D (March 8, 1994, blossom petal fall stage), Kromekote cards were placed at ground level south and downwind of three plots, as shown in Figure 1. Each plot was treated with a different phase of application. Cards were positioned on the ground, every 3 meters in a straight line for 61 meters (200 feet). For the following discussion, data from each drift card line are called by the name of the corresponding treatment plot: drift line 6 (Phase B); drift line 10 (Phase C); and drift line 18 (Phase D).

Deposition along each drift line was measured in drops per square centimeter and ounces per acre, consistent with the canopy deposition data. Drift data for each of the three plots named are shown in Figure 24 (Phase B), Figure 25 (Phase C) and Figure 26 (Phase D), along with FSCBG model predictions. For each plot, deposition in drops per square centimeter is shown on top, with volume deposition in ounces per acre on the bottom. Note that the distance shown is the distance (in meters) along the drift card line, where 0 meters is the edge of the treatment plot and 61 meters is the end of the drift card line. The edge of the treatment plot (the first drift card position) is the edge of the canopy. Zalom et al. (1994) indicate that the pilot stopped spraying at the edge of the canopy; however, there was no record of the spray on/off point during field testing and the on-off point was not precisely at the end of each swath.

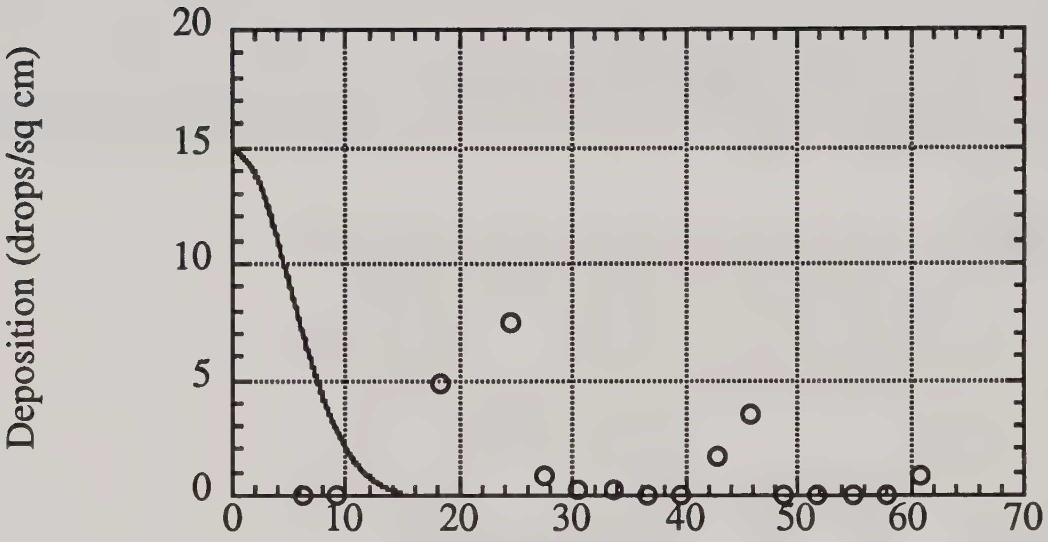
FSCBG drift predictions assume that on-off occurs at the edge of the canopy, at deposition levels equal to the average data deposition level in the canopy. Technically, FSCBG cannot handle a change from canopy to open area; however, a stand alone calculation may be made with the dispersion model from the FSCBG Gaussian equations (Teske et al., 1993b). These results depend on the meteorological conditions for each of the treatments, and are shown by the solid curves in the figures.

It is immediately apparent that there was little downwind drift in Phases B and C of the trials (Figures 24 and 25, respectively). These phases were conducted with the CP nozzle spray system on a helicopter. The amount of deposition measured at the edge of the canopy in Phase B was close to the average deposition levels measured at ground level within the canopy during this phase. Drop and volume deposition at the edge of the canopy in Phase C was much lower than the average level of deposition measured within the canopy, indicating that the canopy had captured most of the spray material, or the on-off location did not occur at the edge of the canopy.

For both phases sprayed with CP nozzles, measured deposition tapered to zero by 20 meters downwind of the canopy edge, indicating minimal drift. This finding is consistent with the previously reported data from a coniferous canopy (Barry et al., 1983). The stand alone drift calculations for Phases B and C also show measured deposition tapering to zero within 20 meters downwind of the canopy edge.

There was significant drift deposition in Phase D (with the Micronair rotary atomizers). Once again, deposition at the beginning of the drift line was approximately at the level of the average ground deposition in the canopy. However, a significant level of material continued to be deposited all along the drift line, which could not be duplicated by

FSCBG. The average level of drops deposited along drift line 18 was 3 drops per square centimeter, and the average volume deposition measured was 4 ounces per acre. If the spray was turned off at the edge of each treatment plot, as is indicated in the field test plan (Zalom et al., 1994), then deposition over the drift lines should mainly be the result of spray which was not absorbed by the canopy. As discussed above, there is minimal deposition over the drift lines from Phases B and C, and significant deposition over the drift line from Phase D. Teske (1995) has demonstrated that a portion of the spray from rotary atomizers may stay aloft for great distances, and perhaps these results confirm this observation.



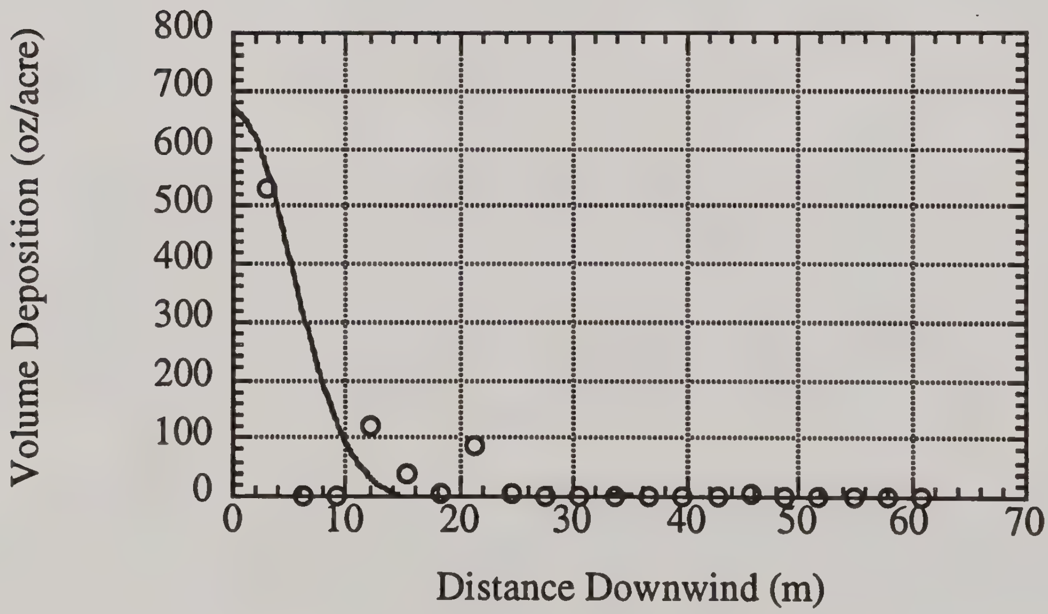
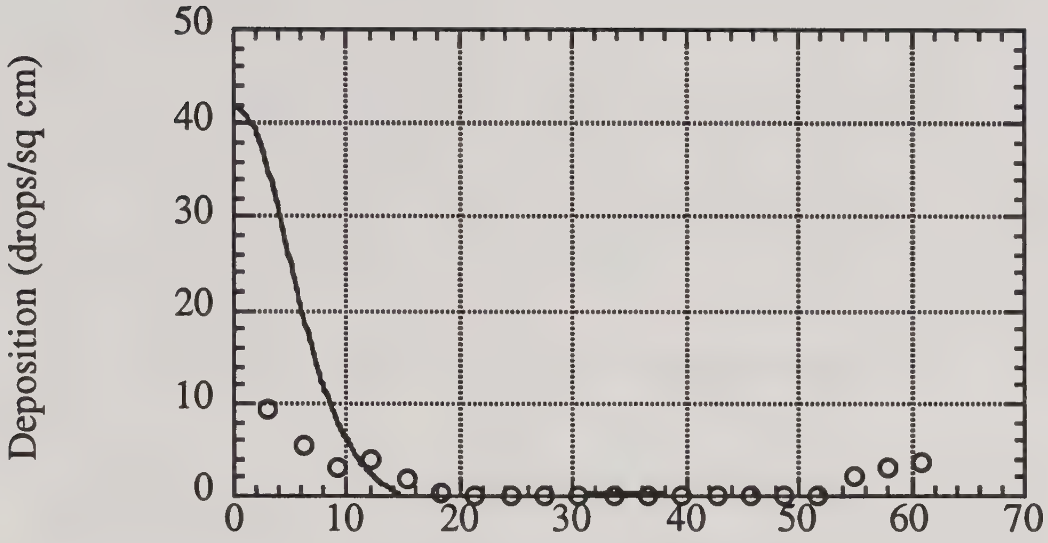


Figure 24: Downwind drift deposition in drops per square centimeter (top) and ounces per acre (bottom) for Phase B. FSCBG predicted drift is shown as a solid curve. Average ground-level drop deposition in the canopy = 15 drops/sq cm. Average ground-level volume deposition in the canopy = 672 oz/acre.



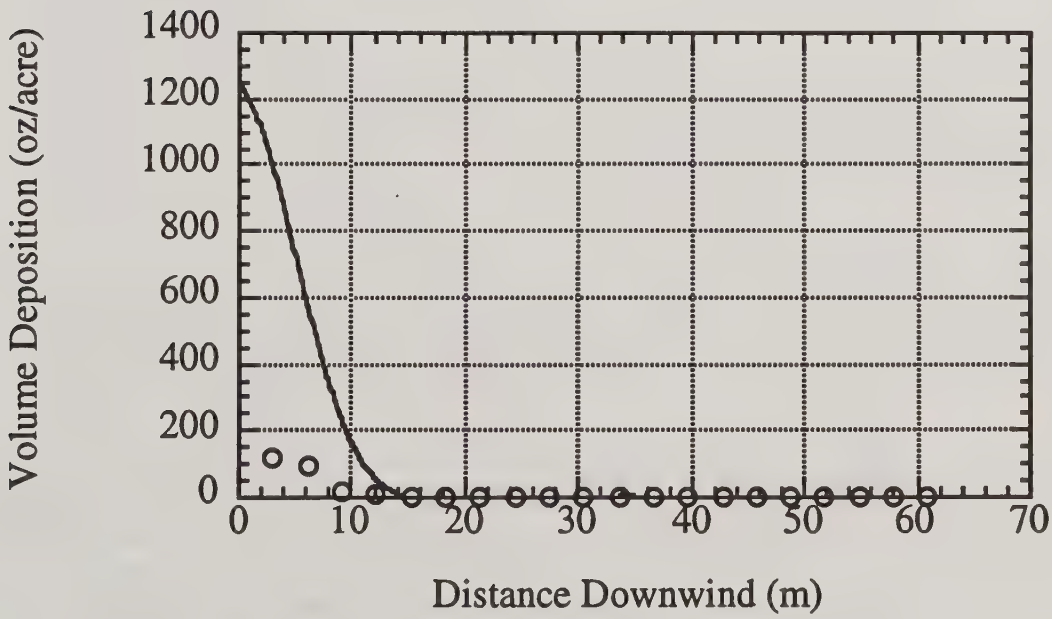


Figure 25: Downwind drift deposition in drops per square centimeter (top) and ounces per acre (bottom) for Phase C. FSCBG predicted drift is shown as a solid curve. Average ground-level drop deposition in the canopy = 42 drops/sq cm. Average ground-level volume deposition in the canopy = 1251 oz/acre.

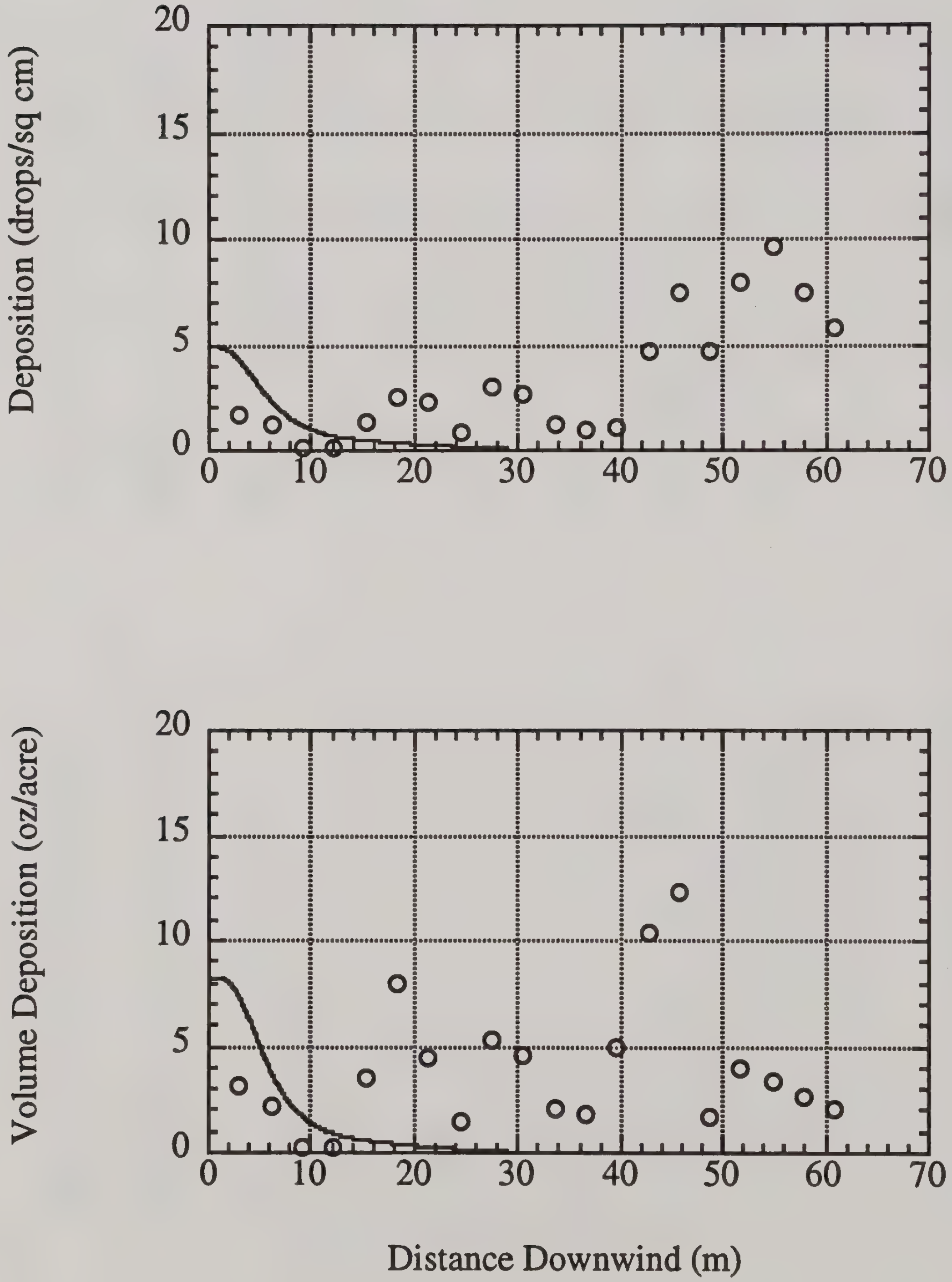


Figure 26: Downwind drift deposition in drops per square centimeter (top) and ounces per acre (bottom) for Phase D. FSCBG predicted drift is shown as a solid curve. Average ground-level drop deposition in the canopy = 4 drops/sq cm. Average ground-level volume deposition in the canopy = 8 oz/acre.

5. Summary of Results

Data from the Hennigan field trials presented in this report provided an opportunity to model a broadleaf canopy at different stages of tree growth. Although exact drop size distributions for the Bt formulation sprayed were not available, FSCBG canopy modeling capabilities were exercised and canopy deposition at two elevations was evaluated. FSCBG predictions of the expected range of deposition over a 12.5 meter swath around the sample trees bracket the average deposition levels observed during the field trials. Predicted deposition levels for Phase D of the trials, using Micronair rotary atomizers, show much better correlation with field data than predicted deposition levels for Phases B and C, which used CP nozzles. Correlation of predictions and actual average deposition shows a least squares slope of 0.49 for volume deposition and 2.25 for drop deposition.

The principal observations made throughout this report may be collected as follows:

1. There is a large amount of scatter to the data collected in the canopy. Even though an almond orchard canopy could be considered uniform, data scatter suggests wide changes in tree shape and capture ability. The field data scatter, and the uniformity of deposition east and west of the sample tree centerline, both confirm the results developed previously (Roltsch et al., 1995).

2. FSCBG model predictions best match the data with penetration probabilities of 0.4 (popcorn stage) and 0.3 (blossom petal fall stage).

3. Although the precise locations of the aircraft flight lines are not known, FSCBG model predictions across a swath width bracketed the canopy field data. Although efforts were made, it was not possible to achieve good correlations of both drop and mass deposition, and a compromise position between both comparisons had to be taken.

4. Predictions of off-canopy drift were consistent with available field data, except for the large drift observed from the smaller particles released from the Micronair rotary atomizer (even though the precise spray on-off point was not known).

As recommended in previous FSCBG model comparison reports (MacNichol and Teske, 1993a, 1993b and 1994), further wind tunnel testing should be done to expand the existing database of drop size characteristics available to FSCBG users. If possible, wind tunnel recovery of drop size distributions should be done with each new set of field studies to ensure that an accurate set of drop distribution data exists for the particular formulation and spray system being tested. As has happened in many FSCBG model comparisons attempted some time after field trials were conducted, exact drop size characteristics and more thorough accounting of aircraft flight path over the test area may have resulted in better prediction of observed deposition.

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